PHD

The effects of unconventional monetary policy in Korea

Park, Nathan

Award date:
2020

Awarding institution:
University of Bath

The Effects of Unconventional Monetary Policy in Korea

Ki-Dok Park

A thesis submitted for the degree of Doctor of Philosophy

University of Bath
Department of Economics

July 2020

Abstract

This thesis analyzes effectiveness of unconventional monetary policy mainly using the approach of New-Keynesian DSGE model which incorporates financial friction. Specifically, Dynamic Stochastic General Equilibrium model explicitly incorporating financial intermediaries like Gertler and Karadi (2011) and Gertler and Karadi (2013) are broadly utilized in the whole part of this thesis. Parameters are usually calibrated using Korean statistics and relevant literatures. Conceptually, in this thesis, enlarging monetary base through large scale asset purchase (LSAP) or foreign exchange intervention (FXI) is defined as typical monetary policy tool used in the implementation of unconventional monetary policy. Furthermore, the relationship between conventional and unconventional monetary policy is also examined in terms of the preferred habitat approach.

In chapter 3, applying Gertler and Karadi (2011) typed New-Keynesian DSGE model into Korean economy, the effectiveness of credit policy is analyzed for the two types of financial shocks. The two types of financial shock are negative capital quality and negative bank net worth shock. Simulation results suggest that credit policy intervention contributes to moderate economic contraction, regardless of negative capital quality shock or bank net worth shock. In chapter 4, it proves that for emerging market economies including features of a small open economy, effectiveness of unconventional monetary policy like the intervention in domestic credit or in foreign exchange market can be very different according to the source of shock during the crisis. Regarding to negative global interest rate shock originated in external sector, it proves that the intervention in foreign exchange market can be more effective than the intervention in domestic credit market in moderating fluctuations of output and inflation. On the other hand, for negative capital quality or bank net worth shock originated in the domestic economy, it turns out that the intervention in domestic credit market is slightly better than the intervention in foreign exchange market in terms of policy effectiveness. In chapter 5, the effectiveness of two monetary policies such as traditional interest rate adjustment and the foreign exchange market intervention using foreign reserve are analyzed based on the model by Aoki, Benigno, and Kiyotaki (2016) which is the open economy version of Gertler and Karadi (2011). It seems that appropriate foreign exchange intervention using foreign reserve can be helpful in boosting inflation and output overall during the downturn. Simultaneously, it also proves that as the intensity of the intervention is stronger, as policy effectiveness is also bigger.

In chapter 6, theoretical differences in policy effectiveness are analyzed in term of three perspectives applying Gertler and Karadi (2013) typed New-Keynesian DSGE model into Korean economy. According to policy simulations, it proves purchase of private securities can be more effective than purchase of long-term government securities when it comes to stabilizing financial market distress and boosting real activities. The result of policy experiment also demonstrates that asset purchase can be more effective when the zero lower bound constraint is maintained for some periods than when the nominal policy rate can be adjusted flexibly in reaction to an asset purchase shock. Finally, the policy effectiveness of an asset purchase can also become weaker when it is postulated that the household cannot directly hold any financial assets like long-term private securities and government securities. In chapter 7, the relationship between conventional and unconventional monetary policy is examined through the approach of “preferred habitat model” of Ellison and Tischbirek (2013) which includes characteristics of canonical New-Keynesian DSGE model. According to optimal monetary policy analysis, it proves that conventional monetary policy instrument like adjustment of short-term nominal policy rate can be harmoniously utilized as a complement with unconventional monetary policy like an asset purchase even though the policy rate is not restricted at zero lower bound. In addition, it also turns out that conducting conventional and unconventional monetary policy together can be considerably contributed to minimize the loss which is composed of the volatilities of short- or long-term government security interest rates.

In sum, considering all the comprehensive simulation results, such a conclusion can be derived that if Bank of Korea conducts unconventional monetary policy utilizing some policy instruments such as asset purchase or foreign exchange intervention, it would be able to considerably contribute to protect the collapse of abrupt financial intermediation in crisis and boost real activities in a deflationary environment. At the same time, it is also evident that according to the characteristic of each exogenous shock, proper unconventional monetary policy instrument under each specific economic situation can be largely different. Hence, in terms of this stance, Bank of Korea would have to be more careful in choosing the non-traditional monetary policy tool when they decide to conduct unconventional monetary policy actively in the future downturn. Furthermore, considering complementarity of conventional and unconventional monetary policy, it seems to be possible the Central Banks in emerging market economies are able to routinely use unconventional monetary policy instrument with traditional adjustment of short-term policy rate in normal time, not just in crisis, although policy rate is not restricted to zero lower bound.

Contents

List of Figures

List of Tables

List of Abbreviations

AE	Advanced Economy
AR	Auto Regressive
BIS	Bank for International Settlements
BOE	Bank of England
BOJ	Bank of Japan
BOK	Bank of Korea
CES	Constant Elasticity of Substitution
CMP	Conventional Monetary Policy
CSV	Costly State Verification
DSGE	Dynamic Stochastic General Equilibrium
ECB	European Central Bank
EFP	External Finance Premium
ELB	Effective Lower Bound
EME	Emerging Market Economy
FLS	Funding for Lending Scheme
FRB	Federal Reserve Board
FX	Foreign Exchange
FXI	Foreign Exchange Intervention
GDP	Gross Domestic Product
GFC	Global Financial Crisis
IMF	International Monetary Fund
IT	Inflation Targeting
LOOP	Law Of One Price
LSAP	Large Scale Asset Purchase
LSP	Loan Support Program
LTRO	Long-Term Refinancing Operation
MBS	Mortgage-Backed Securities
MSB	Monetary Stabilization Bond
NIRP	Negative Interest Rate Policy
NK	New Keynesian
NK-DSGE	New Keynesian-Dynamic Stochastic General Equilibrium
OMO	Open Market Operation
OMP	Optimal Monetary Policy
QEP	Quantitative Easing Policy
RBC	Real Business Cycle
RER	Real Exchange Rate
SMP	Securities Market Programme
SOE	Small Open Economy
SVAR	Structural Vector Auto Regressive
TFS	Term Funding Scheme
TLTRO	Targeted Long-Term Refinancing Operation
UIP	Uncovered Interest Parity
UMP	Unconventional Monetary Policy
VAR	Vector Auto-Regressive
ZIRP	Zero Interest Rate Policy
ZLB	Zero Lower Bound

Acknowledgments

When I decided to start my PhD journey several years ago, I was surrounded by fear because I was not sure about my academic capability and enthusiasm. However, even in the center of such dark clouds, I could find the rainbow due to invaluable advice and help from people. I would like to take this opportunity to express my deep gratitude to my supervisor and parents who have helped me dedicatedly during my PhD journey.

First and foremost, I would like to deeply thank my supervisor, Prof. Christopher Martin for his immensely valuable advice, suggestions, and comments. Sometimes I lost my way and was frustrated in my academic journey. In those ordeals, his truthful encouragements have guided me toward academic destination. I wish to acknowledge his support with deep gratitude.

My deepest gratitude also goes to my parents: to my dad Jangyeol Park and my mom Hongdo Im. Their devoted love and sacrifice have been inspirational to me throughout my entire life. I thank my parents for their endless love and support during my PhD journey from the heart. Without their love, this small achievement would be impossible.

Chapter 1. Introduction: Motivations and Objectives

The distress in global financial markets triggered by bad subprime-mortgage claims in the U.S. was rapidly enlarged into the Global Financial Crisis (GFC) in the late 2008 following the Lehmann Brothers disruption. Many Central Banks tried to counteract this unprecedented financial instability in the credit market and the deterioration of real activity by using traditional measures such as adjusting the nominal policy rate. However, as short-term nominal policy rates reached near the zero lower bound (ZLB), many Central Banks in advanced economies also started to implement unconventional measures[1] including direct intervention in credit markets which is called quantitative easing. In addition, some Central Banks in advanced economies introduced a negative interest rate policy (NIRP) to invigorate the credit channel[2].

Around the same time, some Central Banks in emerging economies implemented rather different types of non-traditional monetary policies. In contrast to advanced economies, the main aim of such policies was to alleviate liquidity distresses in domestic credit or foreign exchange markets. Accordingly, those policy measures were different from those used by Central Banks in advanced economies, comprising an easing of domestic reserve requirements, liquidity injections into foreign exchange markets, currency swap arrangements between the Central Banks, and extending maturities on domestic lending.

The effects of asset purchase policy are now discussed widely amongst academics and policy makers. Especially, as the policy rates have been maintained around the zero lower bound or effective lower bound in many countries since the Great Recession, discussions about optimal combination between existing interest rate policy and asset purchase policy are raised.

In Korea, the policy rate of Bank of Korea is 1.25% as of January, 2020. As the policy rate of Bank of Korea approaches to effective lower bound, the necessity for Bank of Korea to conduct unconventional monetary policy in order to boost real activity is considerably raised recently, compare to the past when the adjustment of interest rate had enough policy space.

Therefore, against this backdrop, my thesis will focus on the following issues:

First part:

- How effective is unconventional monetary policy through credit market intervention in the case where Korea is assumed to be a closed economy?

---

[1] Borio and Zabai (2016) classify unconventional monetary policy into Balance Sheet policy, Forward Guidance, and Negative Interest Rate Policy (NIRP). In addition, according to them, the Balance Sheet policy can be also sorted as Quasi-Debt Management Policy, Credit Policy, and Reserves Policy.

[2] The credit channel can be classified as bank lending and bank capital channel.

Second part:

- How effective is unconventional monetary policy through foreign exchange market intervention in a small open emerging economy such as Korea?

- How different are the effects of unconventional monetary policy through the intervention in the market of domestic credit or foreign exchange when considering Korea is a small open emerging economy?

- How effective is foreign exchange market intervention using foreign reserves transmitted into real or financial sector when considering financial friction in the case of Korea?

Third part:

- How does policy effectiveness differ when the Central Bank purchases private securities or long-term government securities in Korea?

- How effective is asset purchase policy when adjustment of the policy rate is restricted at the zero lower bound in Korea?

- How different is policy effectiveness of asset purchase policy when household segmentation is considered, as in the case of Korea?

Fourth part:

- What is the optimal policy mix between conventional and unconventional monetary policy assuming the policy rate is above the zero lower bound in Korea?

- What is the appropriate policy mix between short-term policy rate adjustment and asset purchase in normal times in terms of maximizing social welfare?

Chapter 2. Literature Review of Unconventional Monetary Policy

The following literature review consists of four parts. In the first part, literatures relating to canonical Dynamic Stochastic General Equilibrium (DSGE) models including New-Keynesian features are reviewed. Second, New-Keynesian models incorporating financial frictions are surveyed, classifying models according to which sector of the economy is affected by the financial friction. Third, the literatures about effects of unconventional monetary policy are examined. Finally, such literatures about examining the effects of asset purchase policy through the approach of the "preferred habitat model" are reviewed.

2.1 Canonical New-Keynesian Models

Examples of canonical Dynamic Stochastic General Equilibrium (DSGE) models incorporating New-Keynesian characteristics such as price or wage stickiness include Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003, 2007). Christiano, Eichenbaum, and Evans (2005) include nominal rigidities when they set price and wage in their model, where these are modelled using a Calvo-type framework. They find that although price stickiness has a relatively limited effect, the rigidity of nominal wages plays a critical role, improving the performance of DSGE models significantly.

Smets and Wouters (2007) build a middle-sized New-Keynesian DSGE model including stickiness of prices and wages. Their model includes a backward-looking element in nominal prices and wages by incorporating indexation to previous inflation rates, as well as fixed cost in production, external habit persistence in consumption, adjustment cost in investment, and variable capital utilization. Disturbances are modeled through seven structural shocks including risk premium, total factor productivity, and monetary policy shocks. With regard to forecasting performance, they find that their model performs as well as a Bayesian VAR model. They argue that in addition to investment adjustment costs both price and wage stickiness are crucial in lowering prediction errors in the model. However, the impact of factors such as an indexation is more limited for forecasting results.

However, there are some limitations in that there is no role for the financial sector in either model. Hence, it seems that the implications of the financial sector for monetary policy effectiveness analysis are not recognized properly in most standard New-Keynesian DSGE models.

2.2 Theoretical New-Keynesian Models with Financial Friction

Approaches to incorporating financial frictions into DSGE models can be broadly classified into two types according to where such financial frictions originate in the model. The first type includes financial frictions on the non-financial borrowers such as the firm (or entrepreneur) or the household side in the model. On the other hand, the second type incorporates financial frictions on the financial intermediaries.

First, Bernanke and Gertler (1989) and Carlstrom and Fuerst (1997) include financial frictions through incorporating an agency problem between lenders and borrowers. Such models are based on a Real Business Cycle (RBC) model with two agents who are entrepreneurs and consumers. The agency problem between entrepreneurs and consumers creates a wedge between costs of internal and external financing. In the model, firms are constrained in their borrowing depending on their net worth. Studies like Bernanke, Gertler, and Gilchrist (1999), Degraeve (2008), and Christensen and Dib (2008) follow this approach.

Alternatively, Kiyotaki and Moore (1997)'s approach is based on costly state verification (CSV) through establishing a collateral constraint on borrowing. Jermann and Quadrini (2012) build a model incorporating financial friction, similar to Kiyotaki and Moore (1997) and Bernanke et al. (1999). Del Negro et al. (2013) also construct a New-Keynesian model which extends the canonical Smets and Wouters (2007) approach by incorporating Bernanke et al. (1999) type financial frictions on the firm side. They argue that their model can predict the rapid deterioration in real activity in the financial crisis of 2008. Furthermore, they also argue that if state dependent nominal rigidities are incorporated into the model, the persistent and modest decrease in inflation can be also matched.

Second, in regard to incorporating financial frictions into the household side of the model, Iacoviello (2005) builds a model of the monetary business cycle including both nominal lending and collateral constraints. In his model, these constraints are closely related with value of housing. Through this mechanism, the impact of shocks is magnified and propagated over time. In this kind of model, the importance of house prices and debt indexation in implementing monetary policy is emphasized.

Iacoviello and Neri (2010) expand the model of Iacoviello (2005) to a middle-sized New Keynesian model. They argue fluctuations in the housing market caused variability in consumption growth in 1989-2006. Guerrieri and Iacoviello (2013) uncover asymmetric responses to the change of housing prices by extending the approach of Iacoviello and Neri (2010).

In a second main approach, an agency problem is assumed between depositors and financial intermediaries in other research. In this type of model, the financial intermediary is constrained in the amount they can lend to non-financial firms depending on their net worth.

For instance, Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) can be considered. To investigate the effects of balance sheet policy by the Federal Reserve since the Great Recession in 2008, Gertler and Karadi (2011) design a model where asymmetric information is assumed between financial intermediaries and depositors. According to their model, changes in financial intermediary's capital or net worth can trigger impacts on borrowing and lending, which affect real activities such as investment and output.

Gertler and Kiyotaki (2010) extend the model of Gertler and Karadi (2011) through incorporating an interbank financial market. In their model, heterogeneous banks are assumed and each bank experiences an idiosyncratic liquidity shock. Accordingly, in addition to the agency problem, the disruption of the interbank loan market can also affect real economic activity. Thus, appropriate intervention in the credit market by the Central Bank can dampen the negative influence of financial frictions during crises.

There are also other approaches to introduce financial frictions into a cannonical New-Keynesian model relating to banking. Goodfriend and McCallum (2007) and Christiano et al. (2010) include a competitive banking sector with multiple financial assets having different returns into a canonical DSGE model. Furthermore, Aslam and Santoro (2008) and Gerali et al. (2010) develop a DSGE model that incorporates a banking sector which is monopolistically competitive.

Curdia and Woodford (2011) develop a New-Keynesian model that includes financial intermediation. In their model, financial imperfection has a critical role as a wedge between lending and borrowing rates. This wedge can be generated by the use of resources in financial intermediation or through the market power of financial intermediaries. Angeloni and Faia (2013) develop a DSGE model that includes bank run. They analyze interactions with regulations on bank capital under the situation that banks are willing to increase their leverage and risk. Gambacorta and Signoretti (2014) also build a DSGE model including financial frictions for evaluating monetary policy design.

There is also a literature that analyses the effectiveness of unconventional policy from an emerging market perspective, including Ishi et al. (2009). They concentrate on the repercussions of different types of unconventional policy between advanced and emerging economies. By contrast with advanced economies, emerging economies had a tendency mainly to use foreign exchange intervention and domestic short-term liquidity easing instruments for counteracting the negative impacts of the Great Recession. They investigate the importance of unconventional policy in emerging economies is less than in advanced economies. This is mainly because of relatively limited financial stress, external vulnerabilities, and the limited scope for quasi-fiscal activities of emerging economies.

In related work, Aoki, Benigno and Kiyotaki (2016) build a model in order to analyze the transmissions of shocks which occur in emerging economies. They make some macro-prudential policy recommendations.

2.3 Effectiveness of Unconventional Monetary Policy from Empirical Perspective

Since the Great Recession, a huge amount of research on examining the effectiveness of various unconventional monetary policy instruments has been conducted from an empirical perspective. A considerable amount of this research argues that unconventional monetary policy measures involving asset purchase programs carried out by some Central Banks in developed economies helped to reduce long-term yields in financial markets and to revive financial intermediation during the crisis.

First, regarding the impacts of unconventional monetary policy by the Fed in the U.S. in the period of the Great Recession, Gagnon et al. (2011) argue asset purchases by FRB were helpful in lowering longer-term interest rates on securities even though some securities were not directly included in the formal large scale asset purchase program. They also argue that longer-term interest rates were lowered due to reduced risk and term premiums rather than through expectations of lower expected future interest rates. Krishnamurthy and Vissing-Jorgensen (2012) reach two conclusions based on an event-study methodology. First, they argue that concentrating on Treasury rates as a policy target of the asset purchase program is not optimal because the asset purchase program can work through various different channels causing different effects on different assets. Second, they also argue that the impact on particular assets can vary according to which types of assets are purchased. Bauer and Rudebusch (2012) find that large scale asset purchases by FRB provoked critical signaling effects which lowered expectation for future short-term interest rates. Meanwhile, using empirical dynamic term structure models, Christensen and Rudebusch (2012) find that U.S. Treasury yields were lowered mainly because of reduced policy expectations, while U.K. yields were lower mainly due to lower term premiums. With a model featuring risk-averse arbitrageurs, Hamilton and Wu (2011) find that historical Treasury factors are useful in predicting yields or excess returns in the period of 1990-2007.

Some research is more skeptical about the effectiveness of the asset purchase by the FRB. For instance, Thornton (2012) is skeptical about the theoretical foundations of the portfolio balance channel in the asset purchase program and presents several arguments why the effectiveness of asset purchases might be limited. Kool and Thornton (2012) also find the effectiveness of an unconventional monetary policy instrument like forward guidance might be different according to the financial and economic conditions of each country conducting it. In particular, even though forward guidance was helpful in improving participants' ability to forecast short-term rates in both Norway and Sweden, it did not strengthen the predictability of monetary policy in New Zealand.

Considering the Eurozone, Peersman (2011) investigates whether the strategy of monetary policy by the ECB for enlarging its balance sheet is different from conventional interest rate innovations. Through estimating a panel VAR for eight advanced economies with monthly data, Gambacorta et al. (2012) find that an exogenous enlargement in the Central Bank balance sheet is helpful for boosting economic activities and consumer prices under the zero lower bound.

Next, considering the unconventional monetary measures conducted by the Bank of England (BOE) in the U.K., Meier (2009) argues that the asset purchases by the BOE were moderately successful. Joyce et al. (2011) also find that the quantitative easing by the BOE was helpful in lowering interest rates by around 80-90bp. Breedon, Chadha, and Waters (2012) find that the asset purchase program by the BOE lowered the yields of government bonds via the portfolio balance channel. They find that yields were lowered by around 50 to 100 bps.

Finally, with regard to Japan's experience of unconventional monetary policy, Ugai (2007) finds that the Quantitative Easing Policy (QEP) conducted by Bank of Japan (BOJ) through March 2001 to March 2006 had limited effects on boosting aggregate demand and prices owing to delayed adjustment in corporate balance sheet and the zero lower bound constraint. Ueda (2012) also finds unconventional monetary measures by BOJ were ineffective in stopping the Japanese deflationary trend although those measures had some impact on asset prices. Lam (2011)'s research also suggests consistent conclusions with the previous research. Using an event study, he finds while unconventional monetary accommodation by BOJ caused statistically considerable effects on reducing government bonds yields and boosting equity prices, it is also evident that there were no clear effects on expected inflations.

2.4 Effectiveness of Unconventional Monetary Policy in Light of Preferred Habitat Model

Vayanos and Vila (2009) develop the Modigliano and Sutch (1966) model. They claim that investors generally regard government bonds having different maturities as imperfect substitutes. From this perspective, they contend that investors are willing to pay some premium in order to purchase government bonds having the specific maturities they prefer.

Chen et al. (2012) argue that the effectiveness of large scale asset purchase policy would be weaker without a commitment to maintain the nominal policy rate at the lower bound for a considerable time. Using a medium-scale DSGE model, they argue that combining non-traditional monetary policy like an asset purchase with a low policy rate stance can be more effective in terms of boosting inflation and output.

Ellison and Tischbirek (2014) analyze effectiveness of unconventional monetary policy based on a preferred habitat assumption. According to their preferred habitat approach, because investors have preference for specific maturities of assets, short- and long- term government securities are regarded as imperfect substitutes. Therefore, they argue that an appropriate policy mix of conventional and unconventional monetary policy can be more helpful in improving social welfare.

Chapter 3. The Effectiveness of Unconventional Monetary Policy in a Closed Economy

3.1 The Model

3.1.1 Overview of Gertler and Karadi Model (2011, GK)

Gertler and Karadi (2011) incorporate New-Keynesian characteristics such as nominal frictions, real frictions, and financial frictions into their model. Nominal frictions represent stickiness and indexation of price. Adjustment costs of investment and utilization of capital are regarded as real frictions. One of interesting features of the model is the clearly specified distinctive role for banks. In contrast to Bernanke, Gertler and Gilchrist (1999), it is assumed banks have perfect information about firm's returns. Accordingly, there is no Costly State Verification (CSV) problem.

There are five kinds of economic agents: households, banks, intermediate good firms, capital producers, and retail firms. Furthermore, the Central Bank implements both of conventional and unconventional monetary policy. It is also postulated the Central Bank performs monetary policy based on a simple Taylor rule.

3.1.2 Households

Each household consumes goods. They also save through lending funds to banks. Households also provide labor. There are two types of member in each household: a fraction $1-f$ are workers; the remainder are bankers. A current banker remains a banker in the subsequent period with probability θ; θ is assumed to be independent of history. $(1-\theta)f$ bankers become workers each period. A former banker gives his total assets to the household. In turn, the household supplies start-up funds to new bankers; these enable a new banker to begin raising deposits and issuing loans and comprise a small portion of total assets.

The household utility function is

$$max\ E_t \sum_{i=0}^{\infty} \beta^i [ln\,(C_{t+i} - \mu C_{t+i-1}) - \frac{\chi}{1+\varphi} L_{t+i}^{1+\varphi}] \tag{3.1}$$

where $0 < \beta < 1$, $0 < \mu < 1$, $\chi, \varphi > 0$. C_t is household consumption and L_t represents the number of working hours. Utility is separable in consumption and labor which is characterized by external habit formation captured by the parameter μ.

The household budget constraint can be described as

$$C_t = W_t L_t + T_t + R_t B_t - B_{t+1} + \Pi_t \tag{3.2}$$

where R_t is the gross real return, B_{t+1} is the short-term debt, W_t is the real wage, T_t is lump sum tax, and Π_t denotes a net payout to the household ownership which includes both of financial and non-financial firms. Both deposits in banks and government debt are one period assets.

Specifically, households deposit funds into the bank in time t and receive non-contingent real gross return R_{t+1} at $t + 1$. Since deposits in banks and government debts are one-period real riskless securities, they are considered as perfect substitutes.

The first order conditions of households with regard to consumption and labor supply can be described as

$$W_t \varrho_t = \chi L_t^{\varphi} \tag{3.3}$$

$$E_t \beta \Lambda_{t\,t+1} R_{t+1} = 1 \tag{3.4}$$

with

$$\varrho_t = (C_t - \mu C_{t-1})^{-1} - \beta \mu E_t (C_t - \mu C_{t-1})^{-1} \tag{3.5}$$

$$\Lambda_{t\,t+1} = \frac{\varrho_{t+1}}{\varrho_t} \tag{3.6}$$

where ϱ_t represents the marginal utility of consumption.

3.1.3 Banks

Banks are competitive. Banks acquire funds from households at non-contingent real rate R_t. Then, bank loans these funds to firms at stochastic loan rate R_{kt}. In addition, since banks purchase long-term assets with short-term deposits or debts, they can transform maturities.

$Bank's\ \ balance\ sheet$:

$$Q_t S_{jt} = N_{jt} + B_{jt+1} \tag{3.7}$$

where Q_t represents the relative price of each financial claim. S_{jt} denotes the sum of financial claims on non-financial firms which bank maintains. B_{jt+1} is the deposit that the bank obtains from households. Lastly, N_{jt} denotes the capital or net worth of the bank.

$Law\ of\ motion\ of\ bank\ capital$:

$$\begin{aligned} N_{jt+1} &= R_{kt+1} Q_t S_{jt} - R_{t+1} B_{jt+1} \\ &= (R_{kt+1} - R_{t+1}) Q_t S_{jt} + R_{t+1} N_{jt} \end{aligned} \tag{3.8}$$

The net worth or capital of an individual bank evolves following equation (3.8). An excess in the return on assets (R_{kt+1}) over the funding cost (R_{t+1}) raises bank profits and so contributes to accumulation of bank net worth. Any growth in bank net worth or capital is dependent not only on the spread of interest rate $(R_{kt+1} - R_{t+1})$ but also on the total quantity of assets $(Q_t S_{jt})$.

$Bank's\ objective$:

Bank's objective is set to maximize the expected discounted net worth of bank or the value of household's financial claims on the bank.

$$V_{jt} = max\ \ E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i}(N_{j\,t+1+i}) \tag{3.9}$$

where $\Lambda_{t,t+1+i}$ denotes the stochastic discount factor.

(Agency Problem of Banks)

Complete information is assumed between banks and firms. This is different from the approach in the influential paper by Bernanke, Gertler and Gilchrist (1999). They postulate an asymmetric information between banks and firms. By contrast, in the Gertler and Karadi (2011) model, there is an asymmetric information between depositors (households) and banks. Meanwhile, banks are able to divert some portion (λ) of their total financial assets, and shift such diverted assets to the household of which he or she is a member. For example, the banker is able to divert some portion of total assets by giving large dividends or bonuses to the household.

$Incentive\ constraint\ for\ lenders\ to\ furnish\ funds\ to\ bank$:

$$V_{jt} \geq \lambda Q_t S_{jt} \tag{3.10}$$

The left-hand side represents the loss which the banker could face if diverting some portion of financial assets. Meanwhile, the right-hand side describes possible benefit from such diversion.

Equation (3.10) reflects the fact that the bank is subject to a limited commitment problem. In other words, the bank can only lend to firms when the payoff from lending (V_{jt}) is larger than the utility from diverting funds ($\lambda Q_t S_{jt}$).

We can express (3.9) as

$$V_{jt} = \nu_t Q_t S_{jt} + \eta_t N_{jt} \tag{3.11}$$

where

$$\nu_t = E_t\{(1-\theta)\beta\Lambda_{t,t+1}(R_{kt+1} - R_{t+1}) + \beta\Lambda_{t,t+1}\theta x_{t,t+1}\nu_{t,t+1}\} \tag{3.12}$$

$$\eta_t = E_t\{(1-\theta) + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\eta_{t,t+1}\} \tag{3.13}$$

where ν_t represents the expected discounted marginal gain to the bank from extending financial assets $Q_t S_{jt}$ by one unit while maintaining bank capital N_{jt} unchanging. η_t represents the expected discounted value of holding additional bank capital N_{jt} while holding S_{jt} constant. $z_{t,t+1}$ denotes the growth rate of net worth and $x_{t,t+1}$ represents the growth rate of total assets.

$$z_{t,t+1} = (R_{kt+1} - R_{t+1})\,\phi_t + R_{t+1} \tag{3.14}$$

$$x_{t,t+1} = \left(\frac{\phi_{t+1}}{\phi_t}\right) z_{t,t+1} \tag{3.15}$$

Hence, the incentive constraint can be expressed as

$$V_{jt} = \nu_t Q_t S_{jt} + \eta_t N_{jt} > \lambda Q_t S_{jt} \tag{3.16}$$

Therefore, when the constraint in (3.10) binds, (3.11) can be expressed as

$$Q_t S_{jt} = \frac{\eta_t}{\lambda - \nu_t} N_{jt} = \phi_t N_{jt} \tag{3.17}$$

Equation (3.17) implies that total lending is a multiple (ϕ_t) of the bank's equity and so ϕ_t represents leverage. Therefore, when there exists an exogenous negative shock to the bank capital or net worth, the volume of total lending will also be decreased. This reduction is magnified by the influence of leverage. This can cause a credit crunch and lead to deterioration in real activity. In conclusion, in the GK model, endogenous constraints on bank's leverage are introduced based on an agency problem, namely that the bank's ability to acquire assets is limited by its capital or net worth.

Figure 3.1: The Commercial Bank Balance Sheet

Assets	Liabilities
Loan Portfolio ($Q_t S_t$)	Deposits (B_t)
	Capital or Net Worth (N_t)

(Aggregate Bank Net Worth)

Aggregate bank net worth is equivalent to the sum of existing bankers' net worth (N_{et}) and new entering bankers' net worth (N_{nt}).

$Law\ of\ motion\ for\ aggregate\ bank\ capital$:

$$N_t = N_{et} + N_{nt} \tag{3.18}$$

A fraction θ of banks in t will remain alive in t+1. Thus, the capital of existing bankers can be described as

$$N_{et} = \theta[(R_{kt} - R_t)\phi_{t-1} + R_t]N_{t-1} \tag{3.19}$$

Household transfers ω of aggregate bank capital. Such capital for new banker is given by

$$N_{nt} = \omega Q_t S_{t-1} \tag{3.20}$$

where 0 < $\omega < 1$

In this model, it is assumed the startup fund that the household furnishes to the new banker in the form of a transfer is equivalent to some portion of total financial assets value[3] which exiting bankers had intermediated in the final business period. Thus, such value of total financial assets in exiting bankers in the final period *t* is equal to $(1-\theta)Q_t S_{t-1}$.

3.1.4 Intermediate Good Firms

There exist many firms producing intermediate goods in a perfectly competition environment. Firms producing intermediate goods obtain capital at the end of *t* to manufacture final goods next period. They sell intermediate goods to retail firms.

To finance financial expenditures, firms issue securities every period. Then, they sell such securities to banks. Capital value is the same as the value of financial claims. In other words, intermediate goods producers finance their capital acquisition from next periods capital stock by borrowing the amount S_t from banks.

$$Q_t K_{t+1} = Q_t S_t \tag{3.21}$$

Intermediate goods producing firms produce Y_{mt} employing capital and labor as inputs. The production technology is assumed to be

$$Y_{mt} = A_t(Z_t \xi_t K_t)^{\alpha} {L_t}^{1-\alpha} \tag{3.22}$$

where A_t denotes total factor productivity. ξ_t is a capital quality shock. This provides a simple exogenous source for variation in the price of capital. Depreciation or obsolescence of capital can be reflected through ξ_t. Thus, $\xi_t K_t$ represents the quantity of effective capital. Z_t denotes the utilization rate of capital.

---

[3] Gertler and Karadi (2010) set this portion to 0.2% of total income in their simulations.

It is postulated that capital replacement costs are fixed and identical to unity. Then, the problem of the intermediate goods firms is

$$\max_{L_t,\ Z_t} \ P_{mt}Y_{mt} + [Q_t - \delta(Z_t)]K_t\xi_t - W_tL_t - R_{kt}Q_{t-1}K_t \tag{3.23}$$

where P_{mt} denotes the price of intermediate goods, δ represents the depreciation rate of capital that is a function of utilization rate (Z_t).

$$\delta(Z_t) = \delta_c + \frac{b}{1+\zeta}Z_t^{1+\zeta} \tag{3.24}$$

where ζ denotes the elasticity of marginal depreciation regarding the utilization rate. Thus, a higher rate of utilization indicates a higher rate of depreciation in capital.

The first order conditions for the utilization rate and labor demand are

$$P_{mt}(1-\alpha)\frac{Y_{mt}}{L_t} = W_t \tag{3.25}$$

$$P_{mt}\alpha\frac{Y_{mt}}{Z_t} = \delta'(Z_t)K_t\xi_t \tag{3.26}$$

Differentiating (3.23) with respect to K_{t+1} gives

$$R_{k\,t+1} = \frac{[P_{mt+1}\alpha\frac{Y_{mt+1}}{\xi_{t+1}K_{t+1}} + Q_{t+1} - \delta(Z_{t+1})]\xi_{t+1}}{Q_t} \tag{3.27}$$

Equation (3.27) suggests the return on bank's financial assets is same with the ex post return to capital because it is postulated all firms which produce intermediate goods earn zero profit.

3.1.5 Capital Producing Firms

In the end of every term, competitive firms which produce capital purchase capital from the firms producing intermediate goods in a competitive market. Capital producers fix depreciated capital and produce new capital. Then, they resell such refurbished capital to intermediate goods producers. The replacing cost for depreciated capital is equal to unity and new capital price per one unit is Q_t. There also exist flow investment adjustment costs related to manufacturing new capital. However, these are restricted to be dependent on net investment flow.

$$\max \ E_t\sum_{\tau=t}^{\infty}\beta^{T-\tau}\Lambda_{t,\tau}\left[(Q_\tau - 1)I_{n\tau} - \Xi\left(\frac{I_{n\tau}+I_{ss}}{I_{n\tau-1}+I_{ss}}\right)(I_{n\tau}+I_{ss})\right] \tag{3.28}$$

where I_t is gross capital created. $I_{n\tau} \equiv I_t - \delta(Z_t)\,\xi_tK_t$ is net capital created and I_{ss} is investment in the steady-state. Equation (3.28) represents discounted profits for a capital producer. Function Ξ implies capital adjustment cost. $\Xi(1) = \Xi'(1) = 0$, and $\Xi''(1) > 0$.

First order condition relating to investment leads to the following capital price equation.

$$Q_t = 1 + \Xi(\cdot) + \frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}}\Xi'(\cdot) - E_t[\Lambda_{t,t+1}(\frac{I_{nt+1}+I_{ss}}{I_{nt}+I_{ss}})^2\Xi'(\cdot)] \tag{3.29}$$

3.1.6 Retail Firms

Similar to other existing DSGE models, nominal rigidities are incorporated via retail goods firms. Retailers purchase goods from intermediate good firms. They combine intermediate goods into differentiated final goods without cost. Then, they sell these final goods in a monopolistic market.

Final product has a form of a composite of intermediate goods. Retail firms produce intermediate goods.

$$Y_t = [\int_0^1 {Y_{ft}}^{\frac{\varepsilon-1}{\varepsilon}} df]^{\frac{\varepsilon}{\varepsilon-1}} \tag{3.30}$$

where Y_{ft} is output produced by retailer *f* and ε denotes the substitution elasticity between goods. ($\varepsilon > 1$)

Through minimization of cost by final output users,

$$Y_{ft} = (\frac{P_{ft}}{P_t})^{-\varepsilon} Y_t \tag{3.31}$$

$$P_t = [\int_0^1 {P_{ft}}^{1-\varepsilon} df]^{\frac{\varepsilon}{1-\varepsilon}} \tag{3.32}$$

Christiano, Eichenbaum, and Evans (2005) include nominal rigidities in their model assuming each retail firm has a probability of $1-\gamma$ of being able to set their price optimally. Retail firms maximize their profits over input demands. Retail firms take their retail prices but the price of final goods is given. Therefore, input demand functions and aggregate price level equation are derived from the first-order conditions of retailers.

$$Y_t = Y_{mt} D_t \tag{3.33}$$

where D_t is an index of price dispersion and Y_{mt} is intermediate goods production.

$$D_t = \gamma D_{t-1} \Pi_{t-1}^{-\gamma_p \varepsilon} \Pi_t^{\varepsilon} + (1-\gamma)(\frac{1-\gamma \Pi_{t-1}^{\gamma p(1-\gamma)} \Pi_t^{\gamma-1}}{1-\gamma})^{-\frac{\varepsilon}{1-\gamma}} \tag{3.34}$$

where $\Pi_t = \frac{P_t}{P_{t-1}}$ is the gross inflation rate and γ is probability of keeping prices fixed.

The optimal price for retailers that are able to re-optimize price (P_t^*) is defined recursively by

$$\Pi_t^* = \frac{\varepsilon}{\varepsilon - 1} \frac{F_{1t}}{F_{2t}} \Pi_t \tag{3.35}$$

where

$$F_{1t} = Y_t P_{mt} + E_t[\beta\gamma\Lambda_{t\,t+1} \frac{\Pi_t^{-\gamma_p\varepsilon}}{\Pi_{t+1}^{-\varepsilon}} F_{1t+1}] \tag{3.36}$$

$$F_{2t} = Y_t + E_t[\beta\gamma\Lambda_{t\,t+1} \frac{\Pi_t^{\gamma_p(1-\varepsilon)}}{\Pi_{t+1}^{(1-\varepsilon)}} F_{2t+1}] \tag{3.37}$$

By equation (3.35), (3.36), and (3.37), optimal pricing reflects expected demand and cost conditions in the future as well as present demand and cost conditions.

Finally, inflation dynamics are given by

$$\Pi_t^{1-\varepsilon} = \gamma \Pi_{t-1}^{\gamma_p(1-\varepsilon)} + (1-\gamma)(\Pi_t^*)^{1-\varepsilon} \tag{3.38}$$

3.1.7 Credit and Monetary Policies

(Credit Policy)

It is supposed the Central Bank facilitates lending during a crisis. The total value of intermediated assets consists of assets intermediated publicly through the government ($Q_t S_{gt}$) and privately intermediated assets ($Q_t S_{pt}$).

$$Q_t S_t = Q_t S_{pt} + Q_t S_{gt} \tag{3.39}$$

During a crisis, the Central Bank can furnish some portion (ψ_t) of total intermediated financial assets.

$$Q_t S_{gt} = \psi_t Q_t S_t \tag{3.40}$$

Because privately intermediated funds are constrained by bank's capital, the total value of financial assets intermediated is given by

$$Q_t S_t = \phi_t N_t + \psi_t Q_t S_t = \phi_{ct} N_t \tag{3.41}$$

where ϕ_t and ϕ_{ct} represent leverage ratios, respectively for privately intermediated and totally intermediated funds.

$$\phi_{ct} = \frac{1}{1-\psi_t} \phi_t \tag{3.42}$$

(Monetary Policy)

The objective of monetary policy is set to stabilize inflation and output. It can be postulated the Central Bank decides the risk-free nominal policy rate on household deposits following a traditional Taylor rule in normal times.

$$i_t = (1-\rho)[i + \kappa_\pi \pi_t + \kappa_y(log\, Y_t - logY_t^*)] + \rho i_{t-1} + \varepsilon_t \tag{3.43}$$

where i_t is the risk-free nominal interest rate. ρ is a smoothing component in interest rate. κ_π is an inflation coefficient and κ_y is an output gap coefficient. ε_t denotes a monetary policy shock which follows an AR(1) process.

The relation between the policy rate and real interest rate can be defined by the Fisher Equation.

$$1 + i_t = R_{t+1}\frac{P_{t+1}}{P_t} \tag{3.44}$$

In a crisis, there is a tendency for credit spreads to rise sharply. Under this kind of environment, I assume that the monetary authority can inject credit in reaction to changes in the domestic credit spread relative to steady state value. The policy reaction rule by the Central Bank in terms of credit supply is

$$\psi_t = \psi + \nu E_t[(log\, R_{kt+1} - log\, R_{t+1}) - (log\, R_k - log\, R)] \tag{3.45}$$

where ψ is the fraction of publicly intermediated financial assets in the steady state. $log\, R_k - log\, R$ is the credit spread in the steady state.

Figure 3.2: The Central Bank Balance Sheet

Assets	Liabilities
Loan $(Q_t S_{gt})$	Debt (B_{gt})

3.1.8 Resource Constraint and Government Policy

The resource constraint in the economy is

$$Y_t = C_t + I_t + \Xi(\frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}})(I_{nt} + I_{ss}) + G + \tau\psi_t Q_t K_{t+1} \tag{3.46}$$

Capital evolves according to the capital accumulation equation.

$$K_{t+1} = \xi_t K_t + I_{nt} \tag{3.47}$$

Finally, government expenditures are assumed to be financed through government intermediation and a lump-sum tax.

$$G + \tau\psi_t Q_t K_{t+1} = T_t + (R_{kt} - R_t)\,\psi_{t-1} Q_t K_t \tag{3.48}$$

where $\psi_{t-1} Q_t K_t$ is the total quantity of government intermediated assets.

3.2 Empirical Results

3.2.1 Calibration

With regard to parameter values, in order to capture the unique macroeconomic characteristics of Korea, parameters are calibrated. Steady-state, average values of recent time-series data, and related literatures are broadly used in order to calibrate these parameters.

In this model, there are 18 parameters. 15 can be regarded as conventional parameters which are often seen in other DSGE literatures, 3 parameters λ, θ, ζ are unique to the Gertler-Karadi model. For θ and ζ, the values in Gertler and Karadi (2011) are used.

Based on Korean data, the depreciation rate is set as 0.002. The labor income share and effective capital share are determined respectively as 0.6 and 0.4. The government expenditure share among output is also calibrated using the average value of government expenditure/nominal GDP from 2000 to 2014. Data prior to 2000 is not used in the calibration process because it is judged that the Korean economy faced a structural break following the East Asian crisis at the end of 1997. Against this backdrop, the ratio of government expenditure per output in steady state is set as 0.137.

In regard to other parameters in the model, similar to Gertler and Karadi (2011), I utilize values of Primiceri et al. (2006). Related parameters are habit persistence, the elasticity in the marginal depreciation relating to utilization rate, the inverse elasticity in net investment to capital value, the inverse Frisch elasticity in labor supply and the price indexation parameter. When it comes to substitution elasticity in goods, I used the conventional value which is widely used in the relevant literatures. In addition, the capital utilization rate is normalized in steady state.

For discount factor, relative utility weight of labor, and price rigidity parameter, the estimated values of Yie and Yoo (2011) are used. For the Taylor rule coefficients of monetary policy, I used the estimation results of Kang (2007). He estimated the coefficients of Taylor rule in Korea. According to his estimation result, the inflation coefficient is 0.085 and output gap coefficient is 0.069 in Korea. Meanwhile, smoothing parameter in Taylor rule is estimated as 0.782.

Table 3.1: Calibrated Parameters

Parameters	Description	Value		Parameters	Description	Value	
		Korea	GK			Korea	GK
β	Discount factor	**0.988**	**0.990**	ζ	Elasticity of marginal depreciation in utilization rate	7.200	7.200
μ	Habit persistence parameter	0.815	0.815	η_i	Inverse elasticity of net investment to capital value	1.728	1.728
χ	Relative utility weight of labor	**12.00**	**3.409**	ε	Substitution elasticity in goods	4.167	4.167
φ	Inverse Frisch elasticity in labor supply	0.276	0.276	γ	Probability of keeping prices fixed	**0.525**	**0.779**
λ	Diverting fraction of capital	**0.374**	**0.381**	γ_p	Measure of price indexation	0.241	0.241
ω	Transfer to the entering bankers	0.002	0.002	κ_π	Inflation coefficient in Taylor rule	**0.085**	**1.500**

θ	Survival rate of bankers	0.972	0.972	κ_y	Output gap coefficient in Taylor rule	**0.069**	**0.5/4**
α	Effective capital Share	**0.400**	**0.330**	ρ	Smoothing parameter in Taylor rule	**0.782**	**0.800**
Z	Capital utilization rate in steady state	1.000	1.000	G/Y	Government's expenditure/nominal GDP ratio in steady state	**0.137**	**0.200**
δ	Depreciation rate in steady state	**0.020**	**0.025**				

3.2.2 Experiment

Gertler and Karadi (2011) simulate the effect of a shock to quality of the bank's financial assets. In this regard, it is designed in their model that the shock to quality of bank's assets amplify the deterioration in the bank's capital because of their high degree of leverage. Based on this type of mechanism, they describe the dynamics of sub-prime crises in the US in 2008.

The objective in this section is not to examine the negative spillover effect of global financial crisis that originated in the US on Korea. Rather, the aim in this section is to capture the dynamics of a crisis that arises in Korea assuming the disruption of Korean financial intermediation and the effects of credit policy intervention. Therefore, even though Korea could experience negative spillover effects from the disruption of financial intermediation that originated in the US in a period of the Global Financial Crisis in terms of a small open economy, this type of global spillover effect on Korea from the US in open economy is not considered in this section.

A closed economy is assumed for simplicity in this section. Later, in chapter 4 and 5, the assumption of a closed economy will be relaxed, so that additional analysis for the crisis occurred in the large country such as the US will be conducted from the perspective of small open economy environment.

(Crisis Simulation)

Since the Great Recession in the late 2008, the repercussion of financial shocks on the real economy has been emphasized. In this part, the transmission mechanism of negative financial shocks such as a deterioration of the capital value of banks is analyzed in a closed economy environment. Two types of negative financial shocks, a capital quality and a bank capital shock are considered.

① Capital Quality Shock (-5%)

First, in order to conduct a crisis experiment in which the capital values of banks in Korea decline rapidly, I postulate that banks experience a negative five percent shock in their capital quality. Intially, it is assumed there is no credit policy intervention by the Central Bank. ($\nu = 0$)

With respect to the transmission mechanism of a negative financial shock, the impact of negative capital quality shock can be classified as having two stages. In the first step, the decline in capital value reduces the quantity of effective capital directly. Then, this reduced effective capital curtails the value of financial assets again. In the second step, the balance sheet of banks is lessened through the bank's leverage constraint. This reduced balance sheet contributes to the decline in asset price and investment. Then, output is also contracted. This kind of circular mechanism of negative financial shock transmission can be magnified through the leverage of the banks.

In figure (3.3), the impulse response functions in reaction to negative five percent capital quality shock show the effective capital stock declines sharply by about -11% level over 3 quarters. In addition, the price of capital declines sharply. It decreases by roughly 14%.

The bank net worth also declines very sharply, by more than -77%. And as a result of such a radically reduced bank net worth, the capability of the banks to lend is also limited. Against this backdrop, the external finance premium (EFP) soars sharply and investment and output decline as a result. Investment declines by about 19.0% immediately and reaches by -28.9% level over three quarters. Output declines by about 3.9% immediately, compared to long-term trend, and converges to the steady state over 80 quarters.

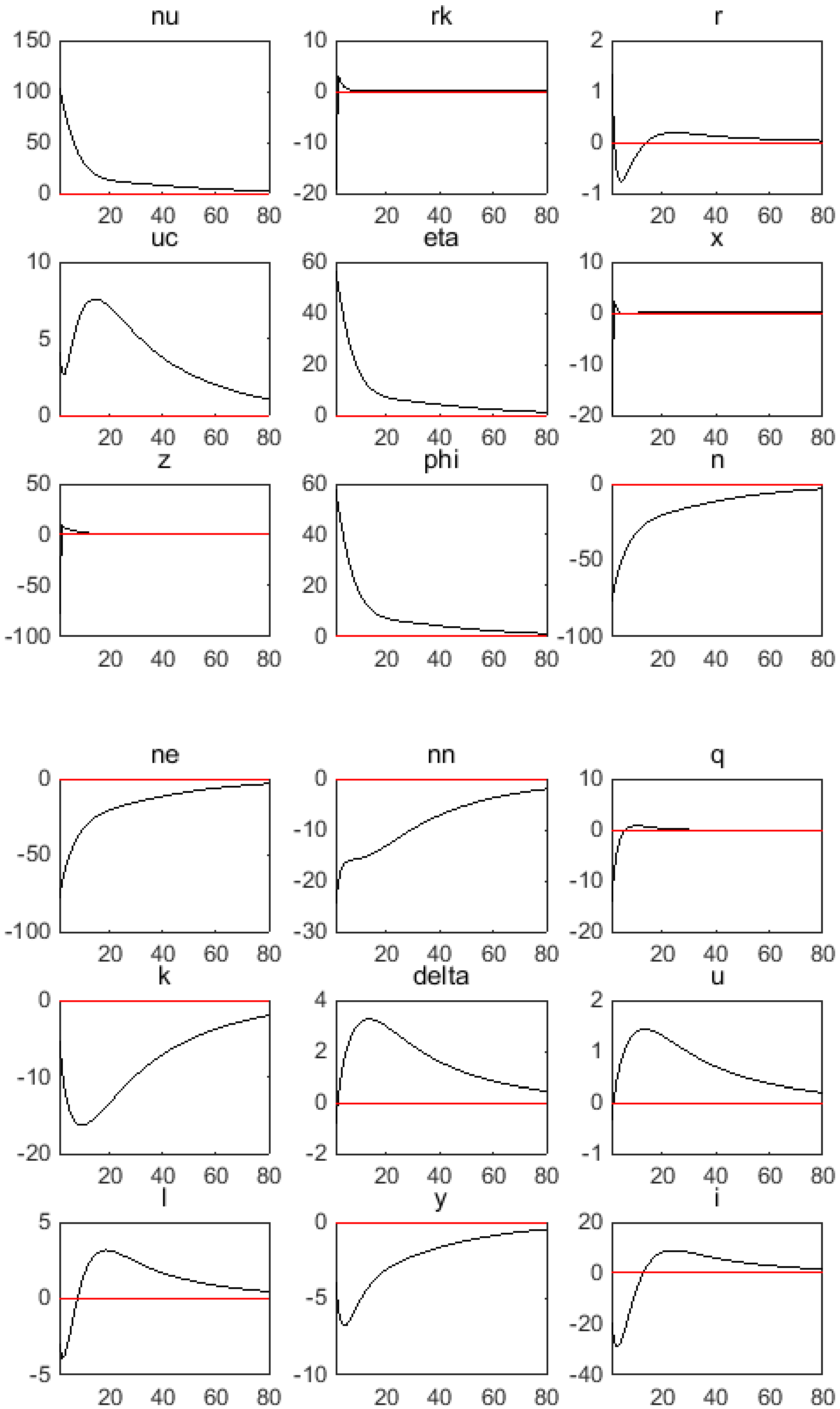
Compared to Gertler and Karadi (2011), impulse response functions show that the Korean economy would also face a similar economic downturn to the US in the late 2008 in the future if similar crisis were to occur due to disruption of domestic financial intermediation. On the other hand, it seems that in Korea the impulse response to a negative capital quality shock is different from the US.

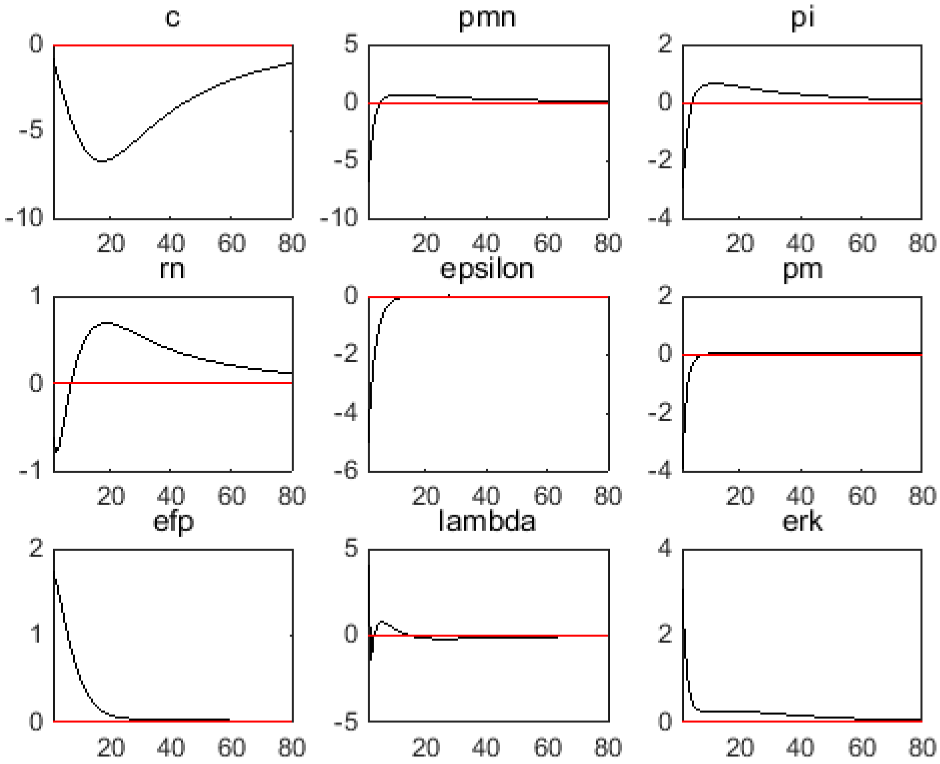
Specifically, the impulse response of the bank's capital is bigger in Korea than in the US. For instance, according to Gertler and Karadi (2011), bank net worth immediately declines to -50% in the US in response to the negative five percent shock. Meanwhile, for the same shock, bank net worth in Korea immediately declines to -77% level.

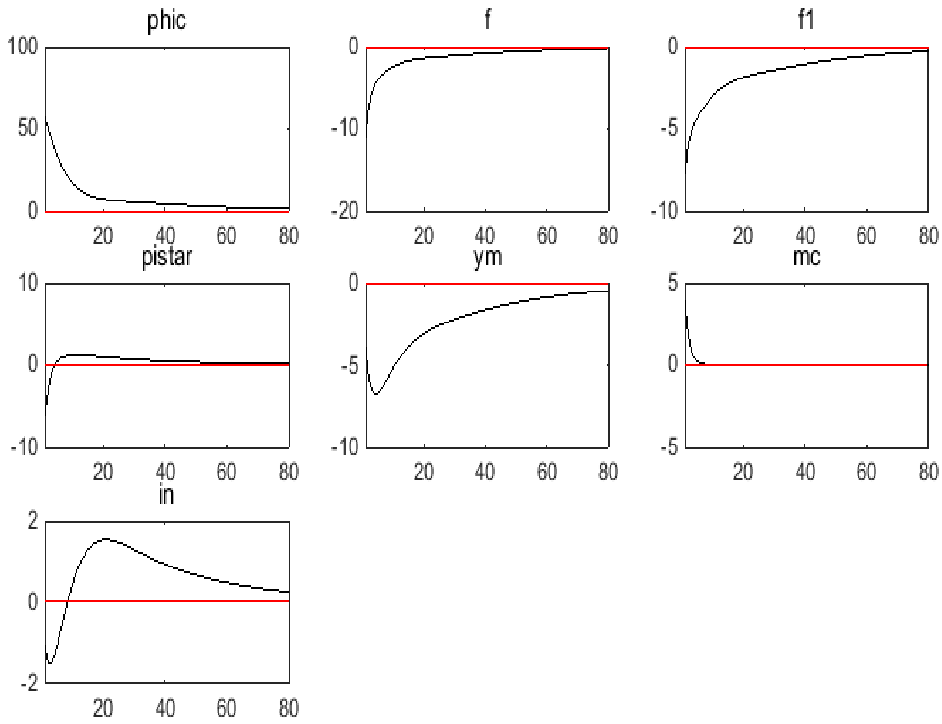
However, for the external finance premium, it turns out the impulse response of external finance premium is smaller in Korea than in the US. Concretely, the external finance premium immediately soars more than five percent in the US in response to a negative five percent shock. For the same shock, the external finance premium in Korea rises immediately by about 1.7%.

For real economy components such as consumption, investment, and output, the influence of the crisis is more persistent in Korea than in the US. Thus, considering all the above simulation results, it seems that if a similar capital quality shock were to occur in the financial sector of Korea, the negative impact would be felt relatively longer in Korea than in the US in 2008.

<u>Figure 3.3: IRFs to a Capital Quality Shock (-5%)</u>




c
0
-5
-10
20 40 60 80
pmn
5
0
-5
-10
20 40 60 80
pi
2
0
-2
-4
20 40 60 80
rn
1
0
-1
20 40 60 80
epsilon
0
-2
-4
-6
20 40 60 80
pm
2
0
-2
-4
20 40 60 80
efp
2
1
0
20 40 60 80
lambda
5
0
-5
20 40 60 80
erk
4
2
0
20 40 60 80


phic
100
50
0
20 40 60 80
f
0
-10
-20
20 40 60 80
f1
0
-5
-10
20 40 60 80
pistar
10
0
-10
20 40 60 80
ym
0
-5
-10
20 40 60 80
mc
5
0
-5
20 40 60 80
in
2
0
-2
20 40 60 80

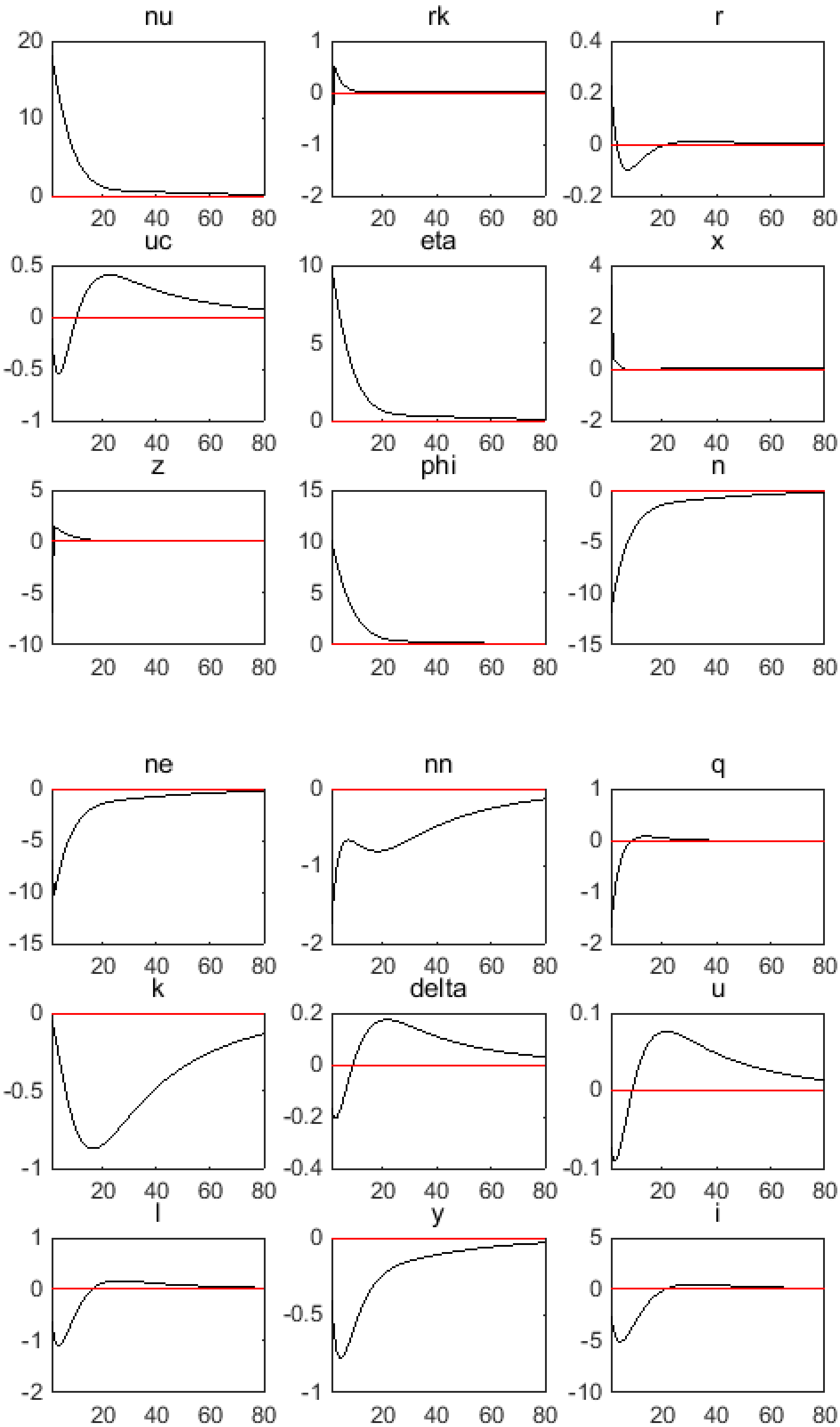
② Bank Net Worth Shock (-5%)

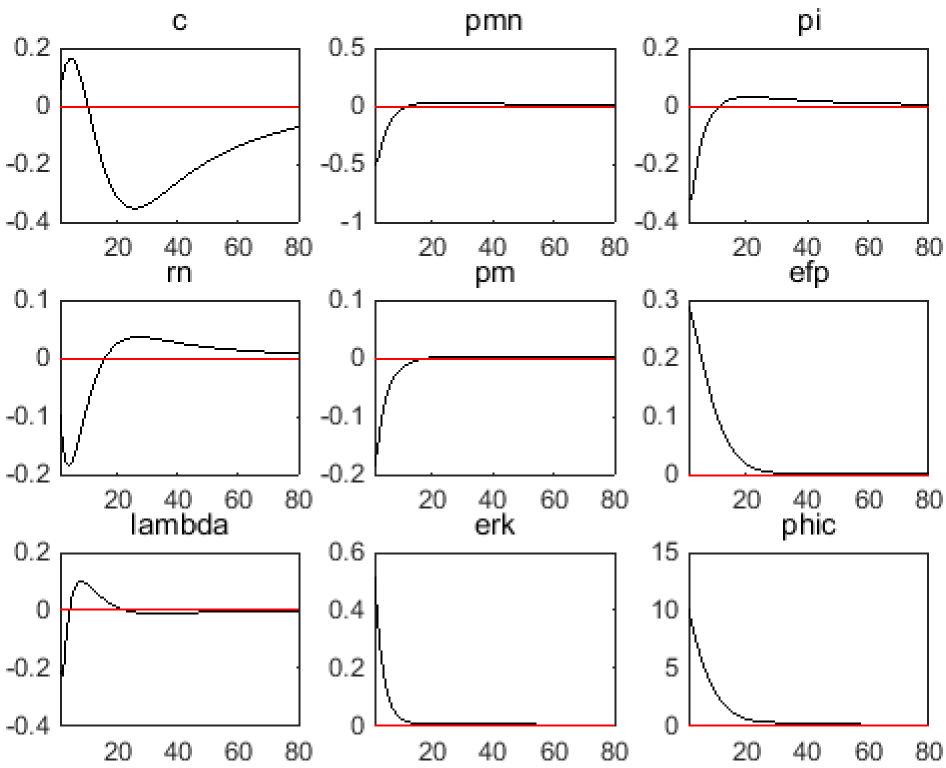
The financial shock can occur not only because of a negative capital quality shock but also because of a negative bank net worth shock. Therefore, a simulation for a negative five percent shock in the bank net worth is also conducted in this section.

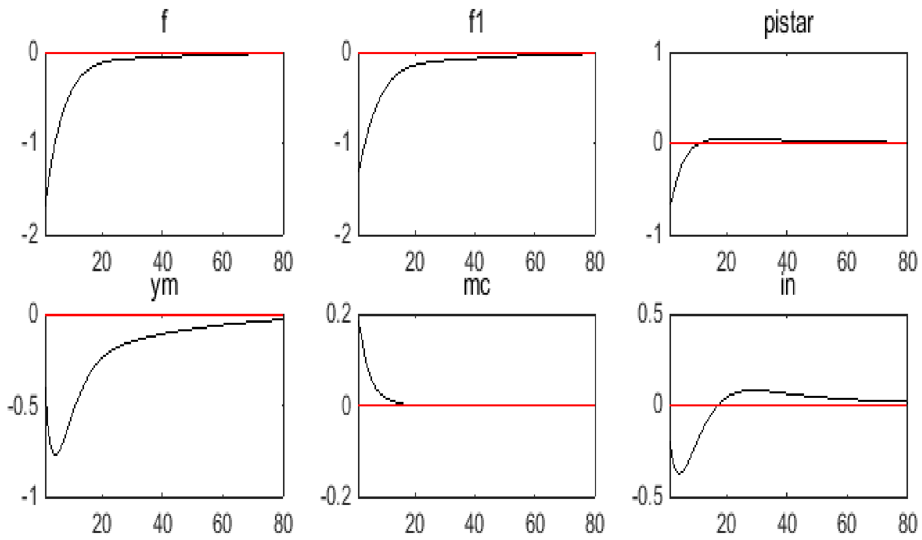
Following a negative five percent shock in the bank net worth, external finance premium soars by 0.29% immediately. In addition, the value of the capital also declines by 1.7%. Simultaneously, with regard to components of real economy, investment reaches -5.5% over four quarters. Output also declines by 0.4% immediately and reaches about -0.77% over four quarters. Inflation also declines to -0.3% instantly.

On the whole, it proves that the negative bank's net worth shock can cause a similar economic downturn compared to the negative capital quality shock. However, for the same degree of the shock (-5%), the negative influence of bank net worth shock are weaker compared to equivalent size of negative capital quality shock.

Figure 3.4: IRFs to a Bank Net Worth Shock (-5%)




c
0.2
0
-0.2
-0.4
pmn
0.5
0
-0.5
-1
pi
0.2
0
-0.2
-0.4
rn
0.1
0
-0.1
-0.2
pm
0.1
0
-0.1
-0.2
efp
0.3
0.2
0.1
0
lambda
0.2
0
-0.2
-0.4
erk
0.6
0.4
0.2
0
phic
15
10
5
0
20
40
60
80


f
0
-1
-2
f1
0
-1
-2
pistar
1
0
-1
ym
0
-0.5
-1
mc
0.2
0
-0.2
in
0.5
0
-0.5
20
40
60
80

(Credit Policy Simulation)

The impact of credit policies by the Central Bank is analyzed for two types of financial shocks. The first financial shock is a negative five percent capital quality shock and another one is a negative five percent net worth shock of the banks. In addition, credit policy by the Central Bank is embedded into the previous model in the shape of a simple feedback rule. In the feedback rule, the feedback parameter (ν) reflects the intensity of credit policy intervention by the Central Bank.

Model is simulated with three feedback parameters: 10, 50, and 100. When ν is equal to 10, it is closer to a real life. On the other hand, when ν is 50, it represents aggressive intervention of credit policy by the Central Bank. Especially, when ν is 100, it shows that the economy is closer to the optimum. It is also supposed the Central Bank conducts both of conventional monetary policy adjusting nominal policy rate and unconventional monetary policy such as asset purchase together. Therefore, the smoothing parameter (ρ) in the Taylor rule of the Central Bank is fixed as zero during the period of the credit policy intervention.

① Intervention for Negative Capital Quality Shock (-5%)

Figure 3.5 shows performance of the credit policy intervention when negative capital quality shock exists. The credit policy intervention for a negative capital quality shock makes the crisis less severe. The credit intervention contributes to moderate the rise of the external finance premium (spread). In addition, the credit policy intervention helps to moderate the fluctuation of output. On the other hand, the influence on inflation seems insignificant because inflation dynamics do not change much after the credit market intervention.

For the intensity of the credit policy intervention, it turns out that when ν is 50, the intervention by credit policy is more effective than when ν is 10. It seems that during a crisis, more aggressive credit policy intervention by the Central Bank can be more effective than a regular liquidity provision in terms of open market operation (OMO) as a stabilization policy.

② Intervention for Negative Bank Net Worth Shock (-5%)

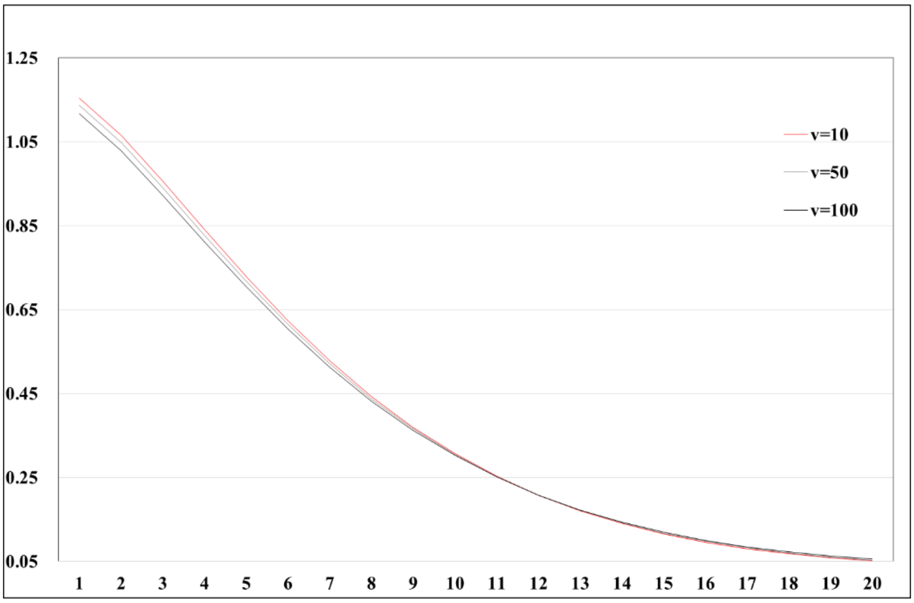
Figure 3.6 shows the performance of the credit policy intervention by the Central Bank when a negative bank net worth shock arises. The credit policy intervention by the Central Bank for negative bank net worth shock also makes the crisis less severe compared to the instance of a negative capital quality shock.

Similarly, the credit policy intervention also helps to reduce the rise in the external finance premium (spread) and helps to moderate the fluctuation of output. The influence of credit policy intervention on inflation is again small.

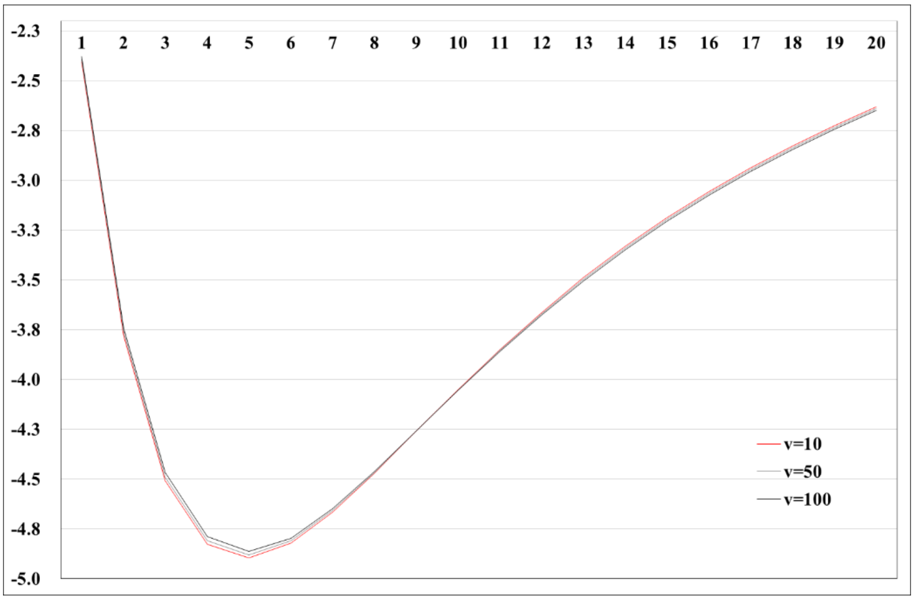
Summarizing, the result of these simulations is that credit policy intervention by the Central Bank contributes to moderate economic contraction regardless of the type of shock. In particular, a more aggressive credit policy intervention is more effective.

Figure 3.5: IRFs to a Capital Quality Shock under Credit Policy

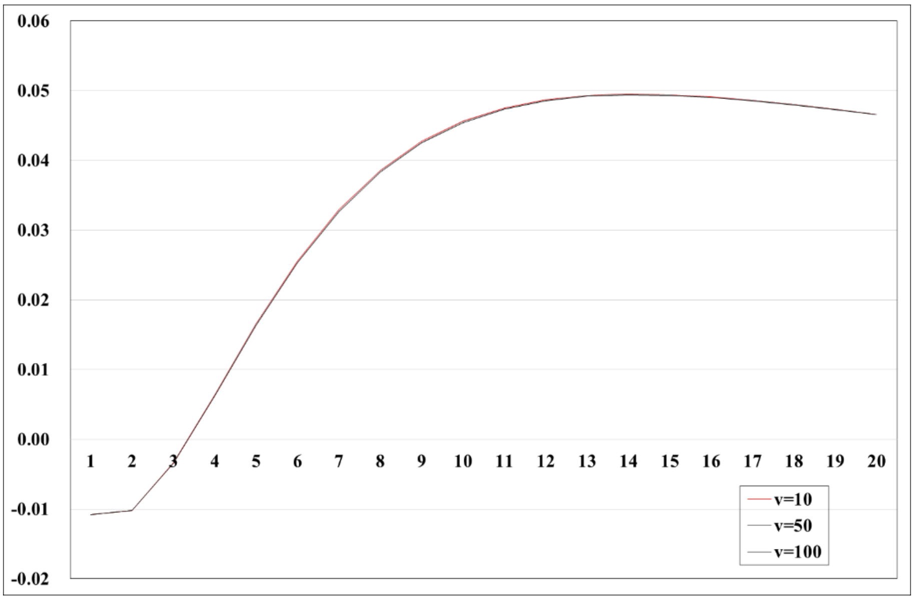
External Finance Premium (Spread)



Output



Inflation



Bank Net Worth (Bank Capital)

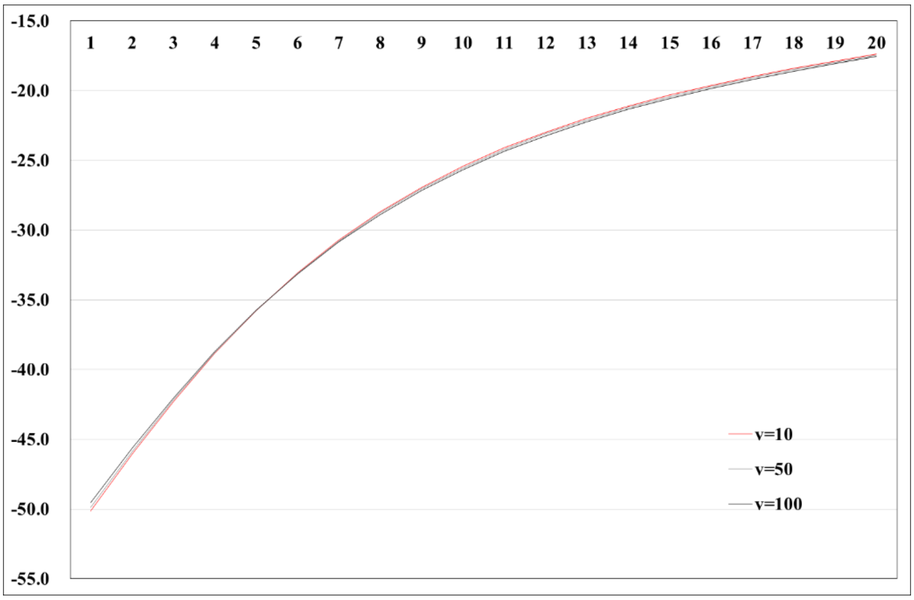
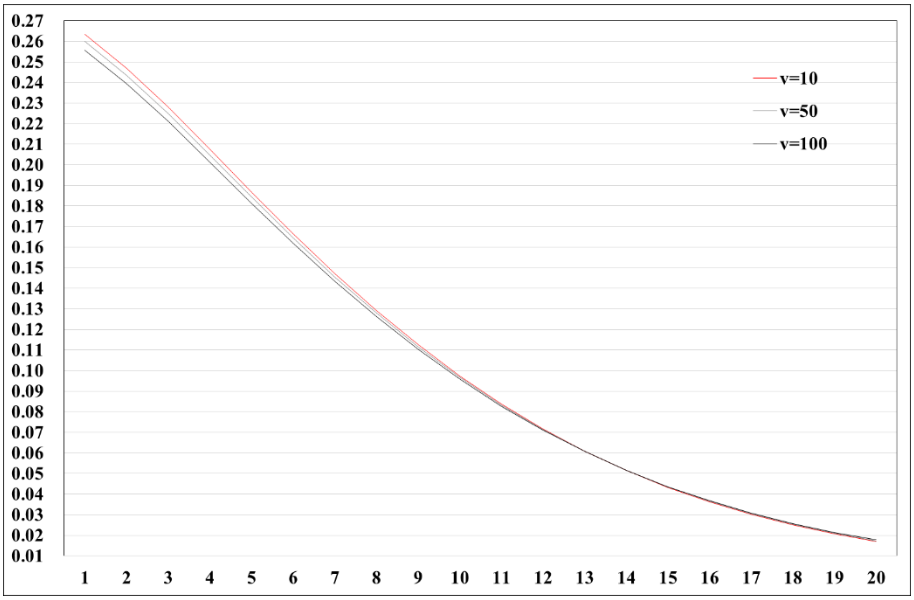
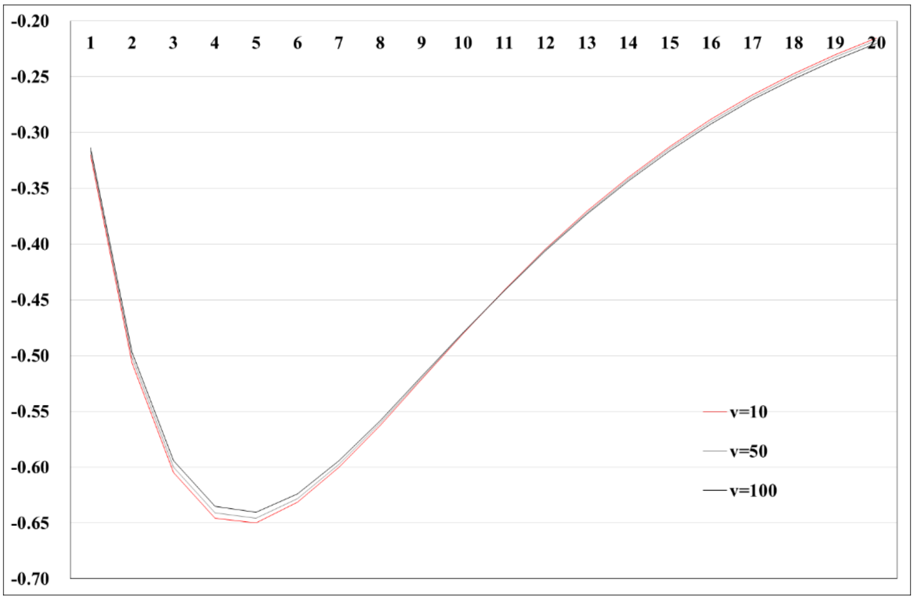


Figure 3.6: IRFs to a Bank Net Worth Shock under Credit Policy

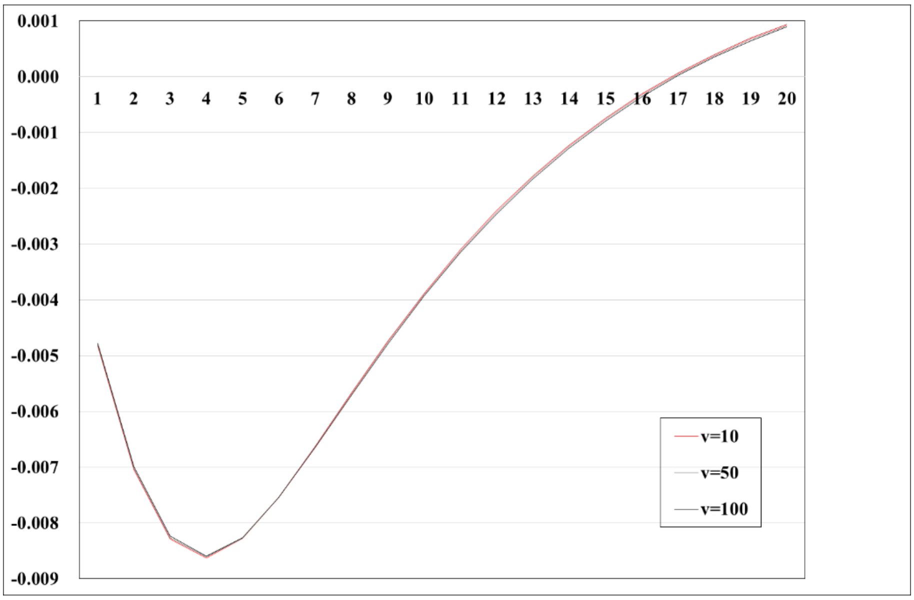
External Finance Premium (Spread)



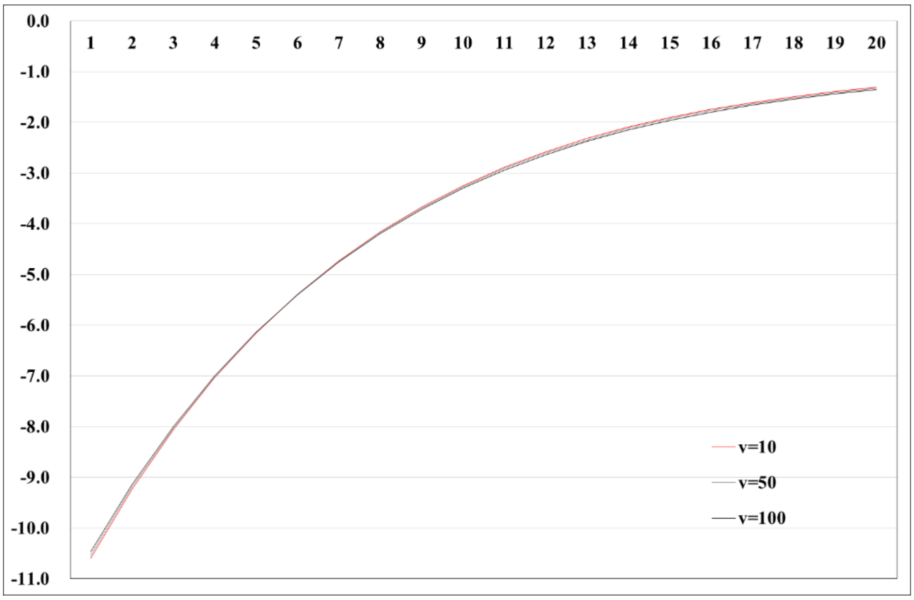
Output



Inflation



Bank Net Worth (Bank Capital)



3.3 Conclusion

In this chapter, applying Gertler and Karadi (2011)'s New-Keynesian DSGE model into Korea, effectiveness of credit policy by the Central Bank is analyzed for two kinds of negative financial shocks. These financial shocks are negative capital quality and negative bank net worth shock. Both of shocks can occur during financial crisis period such as Global Financial Crisis (GFC) in the late 2008 when financial intermediaries collapse.

According to the simulation results, first, the credit policy intervention for negative capital quality shock makes the crisis less severe. For instance, credit policy intervention contributes to lower the rise in the external finance premium (spread). Then, as a result, the credit policy intervention also helps in moderating fluctuation of output. On the other hand, the influence of credit policy on inflation seems insignificant because inflation dynamics does not change considerably even after the intervention in the credit market. In addition, it also proves that during crisis, more aggressive credit policy intervention by the Central Bank can be more effective than a normal liquidity provision like open market operation as a stabilization policy.

Second, the credit policy intervention for a negative bank net worth shock also makes the crisis less severe like the case of negative capital quality shock. Similarly, the credit policy intervention also contributes to reduce the increasing of external finance premium (spread) and is helpful to moderate fluctuation of output. The influence of credit policy intervention on inflation is also trivial like the case of the intervention for negative capital quality shock.

When it comes to policy intervention, the simulation results demonstrate that credit policy intervention by the Central Bank can contribute to moderate economic contraction, regardless of negative capital quality shock or negative bank net worth shock. However, because policy experiment is conducted under the assumption of closed economy, the simulation results in this chapter have some limitations inevitably, when reflecting that Korea is considered as a typical small open economy that can be significantly influenced by capital flow in global capital market or exogenous foreign shocks.

Table 3.2: The Model Summary

Economic Agents	Equation
1. Households	
Stochastic discount factor	$\Lambda_{t\ t+1} = \frac{\varrho_{t+1}}{\varrho_t}$
Euler equation	$E_t \beta \Lambda_{t\ t+1} R_{\ t+1} = 1$
Labor supply	$W_t \varrho_t = \chi L_t^{\varphi}$
Marginal utility of consumption	$\varrho_t = \frac{1}{(C_t - \mu C_{t-1})} - \beta \mu E_t \frac{1}{(C_t - \mu C_{t-1})}$
2. Banks	
Marginal value of bank assets	$\nu_t = E_t\{\beta \Lambda_{t\ t+1}[(1-\theta)(R_{kt+1} - R_{t+1}) + \theta x_{t\ t+1} \nu_{t+1}]\}$
Marginal value of bank capital	$\eta_t = E_t\{(1-\theta) + \beta \Lambda_{t\ t+1} \theta z_{t\ t+1} \eta_{t+1}\}$
Total leverage	$\phi_{ct} = \frac{\phi_t}{1-\psi_t}$
Private leverage	$\phi_t = \frac{\eta_t}{\lambda - \nu_t}$
Increasing rate of bank capital	$z_{t\ t+1} = (R_{kt+1} - R_{t+1})\, \phi_t + R_{\ t+1}$
Increasing rate of bank assets	$x_{t\ t+1} = (\frac{\phi_{t+1}}{\phi_t}) z_{t\ t+1}$
Aggregate capital	$Q_t K_{t+1} = \phi_{ct} N_t$
Net worth evolution	$N_t = N_{et} + N_{nt}$
3.Intermediate Good Producing Firms	
Production function	$Y_{mt} = A_t (Z_t \xi_t K_t)^{\alpha} L_t^{\ 1-\alpha}$
Labor demand	$P_{mt}(1-\alpha)\frac{Y_{mt}}{L_t} = W_t$
Capacity utilization	$P_{mt} \alpha \frac{Y_{mt}}{Z_t} = \delta'(Z_t) K_t \xi_t = b Z_t^{\zeta} K_t \xi_t$
Depreciation rate	$\delta(Z_t) = \delta_c + \frac{b}{1+\zeta} Z_t^{1+\zeta}$
Return on capital	$R_{k\ t+1} = \frac{\left[P_{mt+1} \alpha \frac{Y_{m\ t+1}}{\xi_{t+1} K_{t+1}} + Q_{t+1} - \delta(Z_{t+1})\right] \xi_{t+1}}{Q_t}$
4. Capital Producing Firms	
Net investment	$I_{nt} \equiv I_t - \delta(Z_t)\, \xi_t K_t$
Optimal net investment decision	$Q_t = 1 + \Xi_t + \frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}} \Xi_t{}' - E_t \beta \Lambda_{t,t+1} (\frac{I_{nt+1} + I_{ss}}{I_{nt} + I_{ss}})^2 \Xi_{t+1}{}'$
Investment adjustment cost	$\Xi_t = \frac{\eta_i}{2} (\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}} - 1)^2$
Capital accumulation	$K_{t+1} = \xi_t K_t + I_{nt}$
5. Retail Firms	
Final good production	$Y_t = Y_{mt} D_t$
Price dispersion	$D_t = \gamma D_{t-1} \Pi_{t-1}^{-\gamma_p \varepsilon} \Pi_t^{\varepsilon} + (1-\gamma) (\frac{1 - \gamma \Pi_{t-1}^{\gamma_p (1-\gamma)} \Pi_t^{\gamma - 1}}{1-\gamma})^{-\frac{\varepsilon}{1-\gamma}}$
Inflation dynamics	$\Pi_t^{1-\varepsilon} = \gamma \Pi_{t-1}^{\gamma_p (1-\varepsilon)} + (1-\gamma)(\Pi_t^*)^{\ 1-\varepsilon}$
6. Monetary and Credit Policy	
Monetary policy	$i_t = i_{t-1}^{\rho} (\pi_t^{\kappa_\pi} y_t^{\kappa_y})^{1-\rho} exp(\varepsilon_t^i)$
Credit policy	$\psi_t = \psi + \upsilon E_t[(log\ R_{kt+1} - log\ R_{t+1}) - (log\ R_k - log\ R)]$
7. Other Equations	
Resource constraint	$Y_t = C_t + I_t + \Xi(\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}})(I_{nt} + I_{ss}) + G + \tau \psi_t Q_t K_{t+1}$
Government constraint	$G + \tau \psi_t Q_t K_{t+1} = T_t + (R_{kt} - R_t)\, \psi_{t-1} Q_t K_t$
Fisher equation	$1 + i_t = R_{t+1} \frac{E_t P_{t+1}}{P_t}$

Chapter 4. The Effectiveness of Unconventional Monetary Policy in a Small Open Emerging Economy Ⅰ

4.1 The Model

4.1.1 Overview of extended GK Model in a Small Open Emerging Economy

The closed economy Gertler and Karadi (2011) model can be expanded to a small open emerging economy. Such extension will allow us to assess two unconventional monetary policies conducted by Central Banks in emerging economies since the Great Recession in 2008: liquidity provision to specific export sector and credit enlargement to lower domestic interest rate spreads.

I consider the open economy extension of Gertler and Karadi (2011) (hereafter, GK) model by Cantu Garcia (2013) in which banks can obtain funds not only from domestic depositors but also from global investors. In this model, similar to the closed economy GK model, six kinds of economic agents exist: households, banks, intermediate good firms, capital producers, retail firms, and global investors. The Central Bank is assumed to conduct both conventional and unconventional monetary policies.

With respect to relevant New Keynesian DSGE model, there are not enough studies which review effectiveness of unconventional monetary policy in view of small open economies. Until a recent date, the literatures mainly examine the effectiveness of unconventional monetary policy of large advanced economies such as US and EU. Even though large scale asset purchase program has been conducted in some large economies facing the Global Financial Crisis, conducting asset purchase program in a small open economy is not common owing to limited size or excess liquidity in domestic credit market.

Therefore, some Central Banks in a small open economy such as Czech National Bank conduct intervention policy in a foreign exchange market as a way for enlarging their monetary base to boost real activity, instead of asset purchasing in the bond market. Reflecting this background relating to the use of monetary policy instrument, it seems that the model of Cantu Garcia (2013) is appropriate in analyzing the effects of the foreign exchange market intervention and comparing the effectiveness through foreign exchange market intervention with domestic credit easing in the bond market in Korea.

4.1.2 Households

The modelling of households is similar to GK. Each household consumes goods, purchases financial assets and provides labor. In each household, two kinds of members exist: a fraction $1-f$ is workers; the remainder are bankers. A current banker remains a banker in the subsequent term with probability θ; θ is not time variable. The relative fraction of each sort is not changed. $(1-\theta)f$ bankers become workers each period. A former banker gives his total assets to the household.[4]

[4] The household furnishes new bankers with a start-up fund which is some portion of total financial assets. The size of start-up funds is small. The start-up fund's main purpose is just to give new bankers initial funds with which to begin operations and be able to raise deposits.

The household utility function has a separable form in consumption and labor.

$$max \ E_t \sum_{i=0}^{\infty} \beta^i [ln\ (C_{t+i} - \mu C_{t+i-1}) - \frac{\chi}{1+\varphi} L_{t+i}^{1+\varphi}] \tag{4.1}$$

where $0 < \beta < 1$, $0 < \mu < 1$, $\chi,\ \varphi\ > 0$. C_t is the household consumption. L_t denotes the number of hours worked. Utility has external habit formation which is captured by parameter μ.

The consumption index reflects consumption of both domestically-produced consumption goods (C_{Ht}) and foreign-produced consumption goods (C_{Ft}). A unit substitution elasticity is assumed between domestically and foreign produced consumption products. Meanwhile, it is postulated labor market is competitive.

$$C_t = \ {C_{Ht}}^{1-\varsigma} {C_{Ft}}^{\varsigma} \tag{4.2}$$

The constant substitution elasticity between domestic and foreign consumption products can be decided as ς. This parameter represents expenditure share on each country's products in consumption basket of households.

$$C_{Ht} = \varsigma \frac{P_t C_t}{P_{Ht}} \tag{4.3}$$

$$C_{Ft} = (1-\varsigma) \frac{P_t C_t}{P_{Ft}} \tag{4.4}$$

where aggregate price index is described as

$$P_t = (\frac{P_{Ht}}{\varsigma})^{\varsigma} (\frac{P_{Ft}}{1-\varsigma})^{1-\varsigma} \ = \ \frac{{P_{Ht}}^{\varsigma} {P_{Ft}}^{1-\varsigma}}{\varsigma^{\varsigma}(1-\varsigma)^{(1-\varsigma)}} \tag{4.5}$$

P_{Ht} is the domestic price of domestic consumption products while P_{Ft} represents the domestic price of foreign consumption products.

Domestic and foreign consumption products are traded in a competitive global market. The law of one price (LOOP) implies

$$P_{Ht} = EX_t P_{Ht}^* \tag{4.6}$$

$$P_{Ft} = EX_t P_{Ft}^* \tag{4.7}$$

where EX_t represents nominal exchange rate representing domestic price of foreign currency, P_{Ht}^* represents the foreign price of domestic good while P_{Ft}^* represents the foreign price of foreign product. P_{Ft}^* is set to be normalized to one.

Both deposits of banks and government debt are one period assets paying gross real return which is R_t from $t-1$ to t. These two are both riskless. Therefore, they are considered as perfect substitutes.

Households can make deposits in banks or purchase government bonds. Therefore, household's holdings of short-term debt can be represented as D. Then, household budget constraint can be written as

$$C_t = W_t L_t + R_t D_t - \ D_{t+1} + T_t + \Pi_t \tag{4.8}$$

where W_t denotes the real wage and T_t are lump sum taxes while Π_t stands for a payout to household ownership which include both financial and non-financial firms.

The first order conditions in regard to consumption and labor provision represent next optimality conditions.

$$W_t \varrho_t = \chi L_t^{\varphi} \tag{4.9}$$

$$E_t \beta \Lambda_{t\,t+1} R_{t+1} = 1 \tag{4.10}$$

where the marginal utility of consumption is

$$\varrho_t = (C_t - \mu C_{t-1})^{-1} - \beta \mu E_t (C_t - \mu C_{t-1})^{-1} \tag{4.11}$$

and the stochastic discount rate is $\beta \Lambda_{t\,t+1}$ ($\Lambda_{t\,t+1} = \frac{\varrho_{t+1}}{\varrho_t}$).

4.1.3 Banks

Banks are competitive. They acquire funds from households at the real interest rate (R_t) or from global investors at global gross interest rate (R_t^*). Then, they lend them to non-financial firms at the stochastic loan rate (R_{kt}).

$The\ jth\ bank's\ \ balance\ sheet$:

$$Q_t S_{jt} = N_{jt} + D_{jt} \tag{4.12}$$

where Q_t is the relative price of financial claim. S_{jt} denotes the sum of financial claims on non-financial firms bank retains. D_{jt} denotes the deposits which bank acquires from domestic households and foreign investors. Lastly, N_{jt} is the net worth of bank. Thus, left side represents the value of financial assets of bank while right side is the value of liabilities of bank.

Banks obtain funds not only from domestic depositors but also from global investors by issuing debt contracts. Foreign debt is denominated in the form of foreign currency. It pays global gross interest rate (R_t^*). It is postulated the banks take gross global interest rate as given.

Accordingly, the real interest rate on average bank pays on its' debt is

$$R_{Dt+1} = \frac{e_{t+1}}{e_t} R_t^* \phi_t^* + R_t (1 - \phi_t^*) \tag{4.13}$$

where R_t^* represents the global gross interest rate. ϕ_t^* represents the ratio between foreign and total debt which is proportional of deposits in a bank that come from global investors. e_t is the real exchange rate.

$Law\ of\ motion\ of\ bank\ net\ worth$:

$$N_{jt+1} = (R_{kt+1} - R_{Dt+1}) Q_t S_{jt} + R_{Dt+1} N_{jt} \tag{4.14}$$

Each bank's net worth evolves following equation (4.14). An excess return on assets (R_{kt+1}) over funding cost (R_{Dt+1}) increases the bank's profits. As a result of that, it also increases the bank capital.

$Bank's\ objective$:

The bank's objective is set to maximize bank's terminal net worth, represented as

$$V_{jt} = max\ \ E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i}(N_{jt+1+i}) \tag{4.15}$$

(Agency Problem of Banks)

Complete information is assumed between banks and firms. This is different from Bernanke, Gertler, and Gilchrist (1999) who presumes asymmetric information between banks and firms. Instead, in GK model, an agency problem is set between depositors (households) and banks. Bank is able to divert a portion (λ) of financial assets and transfer such diverted assets to the household of which he or she is a member. In other words, an agency problem through moral hazard of bankers is introduced.

$Incentive\ constraint\ for\ lenders\ to\ furnish\ funds\ to\ bank$:

$$V_{jt} \geq \lambda Q_t S_{jt} \tag{4.16}$$

Left-hand side represents what a banker could lose through diverting a portion of financial assets. Meanwhile, right-hand side represents possible benefit from such diversion.

Equation (4.16) reflects the fact that the bank is subject to a limited commitment problem. In other words, the bank can only lend to firms when the payoff from lending (V_{jt}) is larger than the utility from diverting funds ($\lambda Q_t S_{jt}$).

First, in order to solve bank optimization problem, it is assumed V_{jt} has following functional form.

$$V_{jt} = V_{jt}(S_{jt}, D_{jt}) = u_{st} S_{jt} - u_{dt} D_{jt} \tag{4.17}$$

where u_{st} and u_{dt} represent time-varying marginal values of financial assets which banks hold in the end of each period. After removing D_{jt} in equation (4.17) using equation (4.12), the following equation can be derived.

$$V_{jt} = V_{jt}(S_{jt}, N_{jt}) = \nu_t Q_t S_{jt} + u_{dt} N_{jt} = \nu_t Q_t S_{jt} + \eta_t N_{jt} \tag{4.18}$$

where $\nu_t = \frac{u_{st}}{Q_t} - \eta_t$ denotes the excess value of bank over its deposit. In other words, ν_t is the expected discounted marginal gain to a banker of expanding financial assets ($Q_t S_{jt}$) by one unit, while keeping bank capital (N_{jt}) unchanging. At the same time, η_t represents the expected discounted value of holding another unit of N_{jt}, while maintaining S_{jt} unchanging. ($u_{dt} = \eta_t$)

As the next step, the Bellman equation for the bank's value can be established.

$$V_{jt-1} = V_{jt-1}(S_{jt-1}, N_{jt-1}) = E_{t-1} \Lambda_{t-1,t} \{(1-\theta) N_{jt} + \theta\, max\, V_{jt}(S_{jt}, N_{jt})\} \tag{4.19}$$

In order to maximize $V_{jt}(S_{jt}, N_{jt})$, if Lagrangian method is applied subject to the incentive constraint, the following equation is derived.

$$\mathcal{L}_t = V_{jt} + \gamma_t (V_{jt} - \lambda Q_t S_{jt}) = (1+\gamma_t) V_{jt} - \lambda \gamma_t Q_t S_{jt} \tag{4.20}$$

where $\gamma_t > 0$ when constraint binds and $\gamma_t = 0$ otherwise, γ_t represents a Lagrange multiplier.

The first order conditions based on optimization problem can be described as follow.

$$(1+\mu_t)\nu_t = \lambda\mu_t \tag{4.21}$$

$$V_{jt}(S_{jt}, N_{jt}) = \nu_t Q_t S_{jt} + \eta_t N_{jt} > \lambda Q_t S_{jt} \tag{4.22}$$

Therefore, when constraint is binding, equation (4.23) can be derived.

$$Q_t S_{jt} = \frac{\eta_t}{\lambda-\nu_t} N_{jt} = \phi_t N_{jt} \tag{4.23}$$

The equation (4.19) can be rearranged using equation (4.18) and (4.23).

$$\begin{aligned} V_{jt}(S_{jt}, N_{jt}) &= E_t \Lambda_{t,t+1}\{(1-\theta) + \theta\,(\nu_{t+1}\phi_{t+1} + u_{dt+1})\}N_{jt+1} \\ &= E_t \Lambda_{t,t+1}\eta_{t+1}N_{jt+1} \\ &= E_t \Lambda_{t,t+1}\eta_{t+1}(R_{kt+1}Q_t S_{jt} - R_{t+1}D_{jt}) \end{aligned} \tag{4.24}$$

where $\eta_t = (1-\theta) + \theta\,(\nu_t\phi_t + u_{dt})$

Comparing equation (4.24) with equation (4.17), u_{st} and u_{dt} can be determined.

$$u_{st} = E_t \Lambda_{t,t+1}\eta_{t+1}R_{kt+1}Q_t \tag{4.25}$$

$$u_{dt} = E_t \Lambda_{t,t+1}\eta_{t+1}R_{t+1} \tag{4.26}$$

As a result, the following equation can be derived.

$$\nu_t = E_t \Lambda_{t,t+1}\eta_{t+1}(R_{kt+1} - R_{t+1}) \tag{4.27}$$

Meanwhile, the time-varying marginal values of assets can be also expressed as follow.

$$\nu_t = E_t\{(1-\theta)\beta\Lambda_{t,t+1}(R_{kt+1} - R_{Dt+1}) + \beta\Lambda_{t,t+1}\theta x_{t,t+1}\nu_{t,t+1}\} \tag{4.28}$$

$$\eta_t = E_t\{(1-\theta) + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\eta_{t,t+1}\} \tag{4.29}$$

where $z_{t,t+1}$ represents the increasing rate of bank capital while $x_{t,t+1}$ represents increasing rate of total financial assets.

$$z_{t,t+1} = (R_{kt+1} - R_{Dt+1})\phi_t + R_{Dt+1} \tag{4.30}$$

$$x_{t,t+1} = \left(\frac{\phi_{t+1}}{\phi_t}\right) z_{t,t+1} \tag{4.31}$$

Because ϕ_t is not a factor applied to specific bank, the balance sheet in the banking sector at the aggregate level can be derived.

$$Q_t S_t = \phi_t N_t \tag{4.32}$$

Figure 4.1: The Commerical Bank Balance Sheet

Assets	Liabilities
Loan Portfolio ($Q_t S_t$)	Deposits from Domestic Households and Global Investors (D_t)
	Net Worth or Capital (N_t)

(Aggregate Bank Net Worth)

Aggregate bank net worth is equivalent to the sum of existing bankers' net worth (N_{et}) and new entering bankers' net worth (N_{nt}).

$Motion\ for\ aggregate\ bank\ capital$:

$$N_t = N_{et} + N_{nt} \tag{4.33}$$

Because a fraction θ of banks in t will remain alive until t+1, existing bankers' capital can be described as

$$N_{et} = \theta[(R_{kt} - R_{Dt})\phi_{t-1} + R_{Dt}]N_{t-1} \tag{4.34}$$

Household transfers ω of bank's total capital. New banker's capital can be given by

$$N_{nt} = \omega Q_t S_{t-1} \tag{4.35}$$

where 0 < $\omega < 1$

In this model, it is assumed that startup fund household furnishes its new banker via a transfer is same with some portion of financial assets value exiting bankers had intermediated in the final business period. Thus, exiting bankers' total financial assets in the final period is $(1-\theta)Q_t S_{t-1}$.

(Global Credit Markets)

For banks to borrow funds from domestic depositors or global investors, expected risk-adjusted cost from both sources must be the same. Therefore, the following uncovered interest parity (UIP) condition must hold.

$$E_t\{\beta \Lambda_{t,t+1}[(1-\theta)+\theta\eta_{t+1}][R_t-\frac{e_{t+1}}{e_t}R_t^*]\} = 0 \tag{4.36}$$

The global interest rate (R_t^*) is assumed as the product of two factors. The first factor Γ_t^* is related to global economic state while the other factor (Φ_t) reflects domestic condition.

$$R_t^* = \Gamma_t^* \Phi_t \tag{4.37}$$

where Γ_t^* can be regarded as global interest rate applied for risky financial assets.

The domestic factor reflects the risk of the domestic economy appropriating interest payments by domestic residents to overseas financial institutions, where this risk is an increasing function of external debt of domestic government. Thus, it is assumed that

$$\Phi_t = (-B_t^*)^{\eta^*} \tag{4.38}$$

where $-B_t^*$ denotes net foreign debt of specific country and η^* represents financial imperfection degree.

4.1.4 Intermediate Good Firms

Many firms producing intermediate goods exist under a perfect competition environment. Firms producing intermediate products obtain capital in the end of each period *t* to manufacture final product in the next period. The produced intermediate products are sold to retail firms.

For financing their activities, firm issues securities every period. Then, they sell the securities to banks. Capital price is equivalent to the value of financial claims. In other words, intermediate goods producers finance their capital acquisition for the next period K_{t+1} by borrowing the amount S_t. Through arbitrage,

$$Q_t K_{t+1} = Q_t S_t \tag{4.39}$$

Intermediate goods producing firms produce Y_{mt} utilizing capital and labor as inputs. Production technology for intermediate goods is postulated as

$$Y_{mt} = A_t (Z_t \xi_t K_t)^{\alpha} {L_t}^{1-\alpha} \tag{4.40}$$

where A_t denotes the total factor productivity. ξ_t denotes a capital quality shock which provides a simple source of exogenous capital value's variation. Thus, $\xi_t K_t$ is effective capital quantity. Z_t represents the utilization rate of capital. It is also assumed replacement cost of capital is fixed and identical to unity. Then, problem of intermediate goods firms is

$$\max_{L_t,\ Z_t} \ P_{mt} Y_{mt} + [Q_t - \delta(Z_t)]\xi_t K_t - W_t L_t - R_{kt} Q_{t-1} K_t \tag{4.41}$$

where P_{mt} is the intermediate goods price while δ denotes the depreciation rate in capital which can be represented as a function of utilization rate.

$$\delta(Z_t) = \delta_c + \frac{b}{1+\zeta} Z_t^{1+\zeta} \tag{4.42}$$

where ζ denotes the elasticity of depreciation in regard to utilization rate.

The first order conditions for labor demand and utilization rate are

$$P_{mt}(1-\alpha)\frac{Y_{mt}}{L_t} = W_t \tag{4.43}$$

$$P_{mt}\alpha \frac{Y_{mt}}{Z_t} = \delta'(Z_t) K_t \xi_t \tag{4.44}$$

Differentiating (4.44) with respect to K_{t+1} gives

$$R_{k\,t+1} = \frac{[P_{mt+1}\alpha \frac{Y_{m\,t+1}}{\xi_{t+1}K_{t+1}} + Q_{t+1} - \delta(Z_{t+1})]\ \xi_{t+1}}{Q_t} \tag{4.45}$$

where ξ_{t+1} is a capital quality shock and it gives a source of change in the capital return. Equation (4.45) indicates the return on bank's financial assets is equal to the ex post return to capital because all firms producing intermediate goods earn zero profit under a competitive market.

4.1.5 Capital Producing Firms

In the end of each term, firms which produce capital purchase capital from firms which produce intermediate goods in a competitive market. Capital producers fix depreciated capital and manufacture new capital. Capital producers resell fixed capital to intermediate goods producers. It is presumed replacing cost of depreciated capital is equal to unity. In addition, one unit value of new capital is equivalent to Q_t. There also exist flow adjustment costs related to manufacturing new capital given by $I_{n\tau} \equiv I_t - \delta(Z_t)\, \xi_t K_t$. These are adjustment costs. $I_{n\tau} \equiv I_t - \delta(Z_t)\, \xi_t K_t$ is net capital created and I_{ss} is investment in the steady-state.

$$max\ \ E_t \sum_{\tau=t}^{\infty} \beta^{T-\tau} \Lambda_{t,\tau} \left[(Q_\tau - 1) I_{n\tau} - \Xi\left(\frac{I_{n\tau}+I_{ss}}{I_{n\tau-1}+I_{ss}}\right)(I_{n\tau} + I_{ss})\right] \tag{4.46}$$

where I_t is gross capital created. Equation (4.46) represents discounted profit for capital producer. Function Ξ means capital adjustment cost. $\Xi(1) = \Xi'(1) = 0$, and $\Xi''(1) > 0$.

The first order condition regarding to investment gives an equation for the capital price.

$$Q_t = 1 + \Xi(\cdot) + \frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}} \Xi'(\cdot) - E_t\left[\Lambda_{t,t+1} \left(\frac{I_{nt+1}+I_{ss}}{I_{nt}+I_{ss}}\right)^2 \Xi'(\cdot)\right] \tag{4.47}$$

4.1.6 Retail Firms

Like in other standard New Keynesian DSGE models, retail firms are introduced to add nominal rigidities into the model. Retailers purchase intermediate goods from intermediate good firms. There exists a continuum of firms producing final products who differentiate intermediate products into their own final goods without cost. Then, they sell them in a competitive final goods market including monopolistic features.

Final output has a form of composite of final goods produced by each individual retail firm.

$$Y_{Ht} = \left[\int_0^1 Y_{ft}^{\frac{\varepsilon-1}{\varepsilon}} df\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{4.48}$$

where Y_{ft} is output by retailer *f* and Y_{Ht} is total final output. ε denotes the substitution elasticity between individual final goods (ε > 1).

Through minimization of cost by final output users, the demand for each individual final goods can be shown to be,

$$Y_{ft} = \left(\frac{P_{ft}}{P_{Ht}}\right)^{-\varepsilon} Y_{Ht} \tag{4.49}$$

with

$$P_{Ht} = \left[\int_0^1 P_{ft}^{1-\varepsilon} df\right]^{\frac{\varepsilon}{1-\varepsilon}} \tag{4.50}$$

The retailers choose the optimal price (P_{Ht}^*) for maximizing their profits.

$$max\ \ E_t \sum_{\tau=t}^{\infty} \gamma^\tau \beta^\tau \Lambda_{t,t+\tau} \left[\frac{P_{Ht}^*}{P_{H\,t+\tau}} \prod_{k=1}^{\tau} (1 + \pi_{Ht+k-1})^{\gamma_p} - P_{m\ t+\tau}\right] Y_{f\ t+\tau} \tag{4.51}$$

where $\pi_{Ht} = \frac{P_{Ht}}{P_{Ht-1}}$ is the gross domestic inflation rate.

The first order condition for optimal domestic price for retailers is

$$E_t \sum_{\tau=t}^{\infty} \gamma^{\tau} \beta^{\tau} \Lambda_{t,t+\tau} \left[\frac{P_{Ht}^{*}}{P_{H\,t+\tau}} \prod_{k=1}^{\tau} (1+\pi_{t+k-1})^{\gamma_p} - \frac{1}{1-\frac{1}{\varepsilon}} P_{m\,t+\tau} \right] Y_{f\,t+\tau} = 0 \tag{4.52}$$

As a result, aggregate domestic price can be also derived.

$$P_{Ht}^{1-\varepsilon} = \gamma(\pi_{t-1}^{\gamma_p} P_{Ht-1})^{1-\varepsilon} + (1-\gamma)(P_{Ht}^{*})^{1-\varepsilon} \tag{4.53}$$

Equation (4.53) can be expressed in the form of inflation term as the following. Hence, finally, domestic inflation dynamics are given by

$$\pi_{Ht}^{1-\varepsilon} = \gamma \pi_{Ht-1}^{\gamma_p(1-\varepsilon)} + (1-\gamma)(\pi_{Ht}^{*})^{1-\varepsilon} \tag{4.54}$$

4.1.7 Monetary, Credit, and Foreign Exchange Policies

The monetary policy goal is set in order to stabilize inflation and output. Basic assumption is the Central Bank is able to decide the risk free nominal rate (i_t) on household deposits following a traditional Taylor rule.

$$i_t = (1-\rho)[i + \kappa_\pi \pi_t + \kappa_y (logY_{Ht} - logY_H^*)] + \rho i_{t-1} + \varepsilon_t \tag{4.55}$$

where i_t is the risk-free nominal rate. ρ is an interest rate smoothing component. κ_π is the inflation coefficient and κ_y is the output gap coefficient in Taylor rule. ε_t denotes an interest rate shock which is presumed as following an AR(1) process.

According to the Fisher Equation, the relation for real and nominal interest rate is set.

$$1 + i_t = R_{Dt+1} \frac{P_{t+1}}{P_t} \tag{4.56}$$

In this model, Central Banks also conduct two kinds of unconventional monetary policy. First one is the intervention in the domestic credit market by providing direct loan to domestic non-financial firms. Meanwhile, second one is the intervention in a foreign exchange market.

(Domestic Credit Market Intervention)

In normal time, it is assumed monetary policy is conducted based on a conventional monetary policy rule such as the Taylor rule. However, during a crisis, there is a tendency for credit spreads to rise sharply. In this kind of environment, I assume that the Central Bank supplies credit in response to changes of credit spread following a simple feedback rule.

$$\psi_t = \psi + \nu[(log\, R_{kt} - log\, R_t) - (log\, R_k - log\, R)] \tag{4.57}$$

where ψ represents a fraction of publicly intermediated financial assets in the steady state and $log\, R_k - log\, R$ denotes the credit spread (premium) in the steady state.

(Foreign Exchange Market Intervention)

The Central Bank can also intervene in a foreign exchange market for adjusting the real exchange rate using foreign reserves. Following the assumption of Garcia-Cicco (2011), the uncovered interest parity (UIP) becomes

$$E_t\{\beta \Lambda_{t,t+1}[(1-\theta) + \theta \eta_{t+1}][R_t - \frac{e_{t+1}}{e_t} R_t^*]\} = \varphi(\triangle FX_t) \tag{4.58}$$

where φ represents the sensitivity of deviations from uncovered interest rate parity to foreign exchange interventions. FX is the foreign reserve which is owned by the Central Bank ($\triangle FX_t = FX_t - FX_{t-1}$).

The Central Bank changes exchange rate by changing amount of foreign reserves. It is assumed the Central Bank alters the quantity of foreign reserve in response to the credit spread in global financial market. Feedback rule of the Central Bank is described as

$$FX_t = FX + \nu^*[(log\, R_t - log\, R_t^*) - (log\, R - log\, R^*)] \tag{4.59}$$

where FX represents the foreign reserves in the steady state and $log\, R - log\, R^*$ represents the interest rate spread (premium) in the steady state.

Figure 4.2: The Central Bank Balance Sheet

Assets	Liabilities
Loan $(Q_t S_{gt})$	Debt (D_{gt})
Foreign Reserves (FX_t)	

4.1.8 Resource Constraint and Government Policy

The economy wide resource constraint is

$$Y_{Ht} = C_{Ht} + C^*_{Ht} + I_{Ht} + \Xi\left(\frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}}\right)(I_{nt} + I_{ss}) + G + \tau\psi_t Q_t K_{t+1} \tag{4.60}$$

The domestic output (Y_{Ht}) is utilized for domestic consumption, foreign consumption, domestic investment, government consumption, and expenditures on financial intermediation.

On the other hand, capital evolves according to following the capital accumulation equation.

$$K_{t+1} = \xi_t K_t + I_{nt} \tag{4.61}$$

The demand for domestic good of foreign consumers is expressed as

$$C^*_{Ht} = C^*(P^*_{Ht})^{-v^*} \tag{4.62}$$

where C^* represents the foreign demand for domestic good and is assumed as exogenous and constant for simplicity.

Finally, expenditures of government are funded through lump sum taxes and government intermediation.

$$G + \tau\psi_t Q_t K_{t+1} = T_t + (R_{kt} - R_t)\,\psi_{t-1} Q_t K_t \tag{4.63}$$

where $\psi_{t-1} Q_t K_t$ is the quantity of government intermediated assets.

In addition, through aggregating budget constraints of the Central Bank and households, following balance of payments described as foreign currency term is derived.

$$P^*_{Ht} C^*_{Ht} - C_{Ft} - I_{Ft} = B^*_t - R^*_{t-1} B^*_{t-1} + FX_t - R^*_{t-1} FX_{t-1} \tag{4.64}$$

where I_{Ft} represents the imported foreign good component of investment.

4.2 Empirical Results

4.2.1 Calibration

With reference to parameter values, to capture the unique macroeconomic characteristics of Korea, parameters are calibrated similar to in chapter 3. Steady-state, average values of recent time-series data, and related literatures are used in calibrating parameters exogenously. In this extended model, the total number of parameters is 24. 6 parameters are additionally included compared to the closed economy Gertler and Karadi (2011) model in chapter 3. The parameter values in chapter 3 are consistently used if they are relevant in this model.

On the other hand, some parameters relevant to a small open economy are calibrated newly. Specifically, preference bias for home goods is set following Lee and Yeo (2008). In addition, with regard to the ratio of foreign debt among total debt, the statistical value of money-flow tables as of the fourth quarter of 2015 is used. For the remaining parameters of export price elasticity, exogenous factor in foreign demand, curvature of international credit supply curve, and influence of change in foreign reserve on uncovered interest parity, I follow the values used in Garcia's paper. For the Taylor rule coefficients, standard values are widely used. Coefficient on inflation and coefficient on output in standard Taylor rule is set as 1.5 and 0.5, respectively. In addition, smoothing parameter is assumed as 0.782.

Table 4.1: Calibrated Parameters

Parameters	Description	Value		Parameters	Description	Value	
		Korea	Garcia			Korea	Garcia
β	Discount factor	**0.988**	**0.990**	ζ	Marginal depreciation elasticity in utilization rate	7.200	7.200
μ	Habit persistence parameter	0.815	0.815	η_i	Inverse elasticity of net investment to capital value	1.728	1.728
χ	Relative utility weight of labor	**12.00**	**3.409**	ε	Substitution elasticity in goods	4.167	4.167
φ	Inverse Frisch elasticity in labor supply	0.276	0.276	γ	Probability of keeping prices fixed	**0.525**	**0.779**
λ	Diverting fraction of capital	**0.374**	**0.381**	γ_p	Measure of price indexation	0.241	0.241
ω	Transfer to entering bankers	0.002	0.002	κ_π	Inflation coefficient in Taylor rule	**1.500**	**2.043**
θ	Survival rate of bankers	0.972	0.972	κ_y	Output gap coefficient in Taylor rule	**0.500**	**- 0.50**
α	Effective capital Share	**0.400**	**0.330**	ρ	Smoothing parameter in Taylor rule	**0.782**	**0.800**
Z	Capital utilization rate in steady state	1.000	1.000	G/Y	Gov't expenditure/output ratio in steady state	**0.137**	**0.200**
δ	Depreciation rate in steady state	**0.020**	**0.025**				
< Additional Parameters in a Small Open Economy >							
v^*	Export price elasticity	1.000	1.000	ϕ^*	Ratio between foreign and total debt	**0.091**	**0.300**

C^{*}	Exogenous factor in the foreign demand	0.424	0.424	η_{Ω}	Curvature of the int'l credit supply curve	0.167	0.167
ς	Preference bias for home goods	**<u>0.600</u>**	**<u>0.550</u>**	φ	Influence of change in foreign reserves on UIP	0.204	0.204

4.2.2 Experiment

(Crisis Simulation in a Small Open Economy)

The crisis experiments for three types of shocks are conducted. Those three shocks for the crisis are the global interest rate shock (+25bp), the capital quality shock (-5%), and the bank net worth shock (-5%).

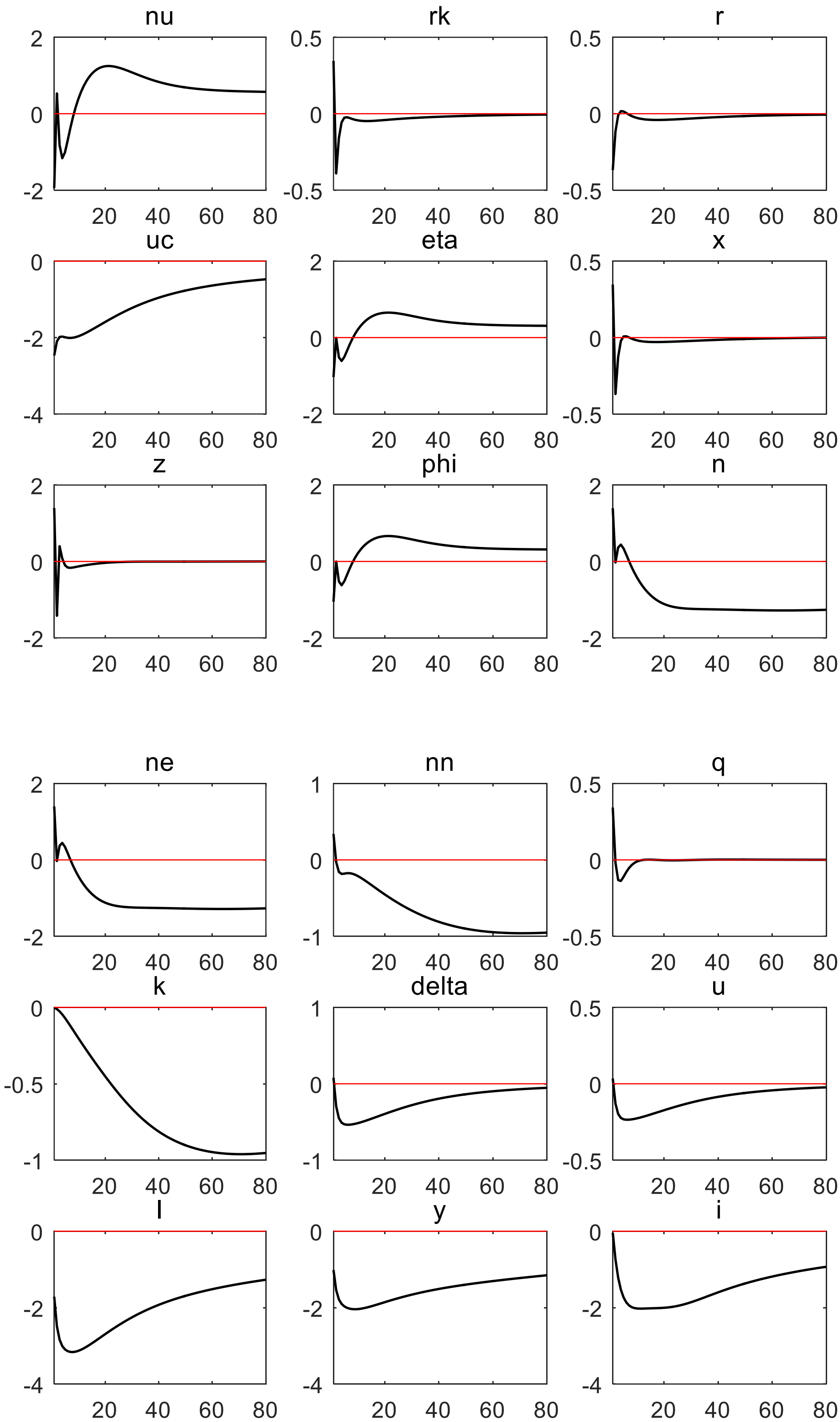
① Global Interest Rate Shock (+25bp)

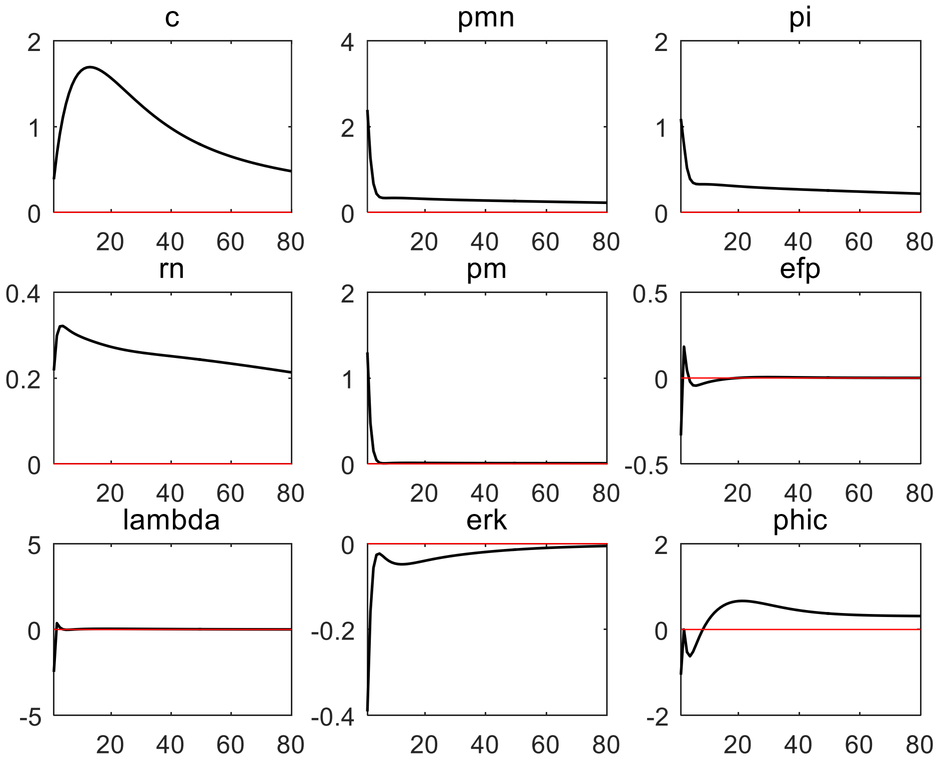
The impacts of an increase in global interest rate applied to small open economies (SOEs) or emerging market economies (EMEs) is analyzed. As explained before, underlying assumption is that global interest rate is the product of global factor and local factor and there is +25bp shock in global interest rate due to some financial crisis. With respect to the shock, global factor affecting the global interest rate is represented as rstar in AR(1) process in the model. In addition, autoregressive coefficient of the global factor shock (rstar) is assumed as 0.95. It is also assumed that there is not any credit and foreign exchange intervention in the simulation. ($\nu = 0$ and $\nu^{*} = 0$)

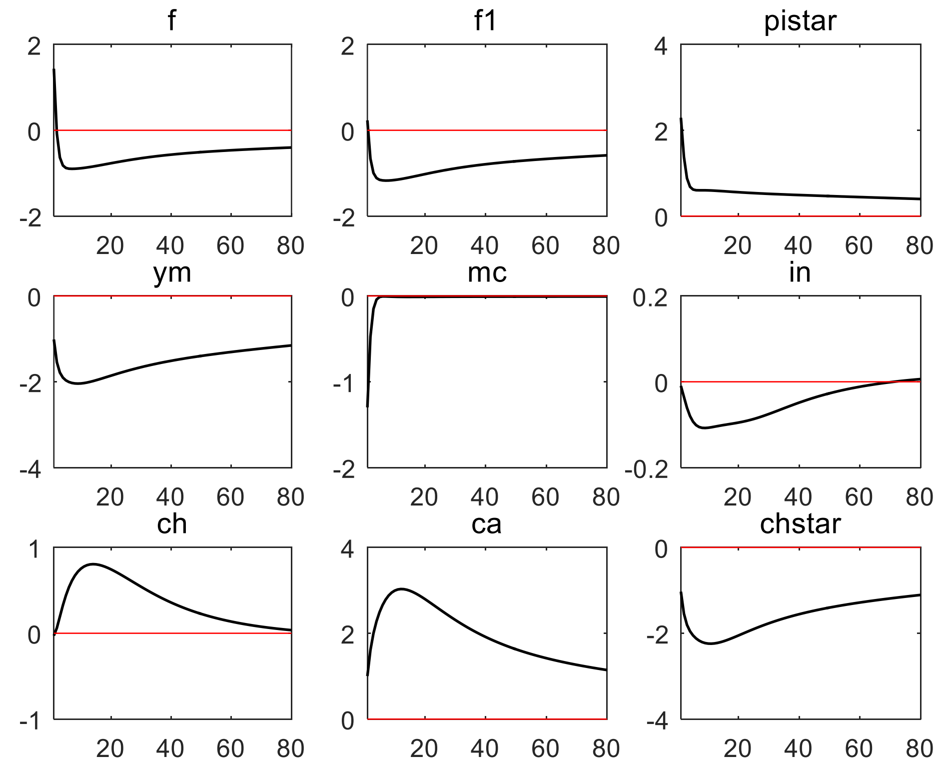
Regarding the transmission mechanism of global interest rate shock, the increase in global factor affecting global interest rate represents a global risk aversion for emerging market economies which is amplified due to some global recession or crisis. Therefore, through this type of shock, around the Global Financial Crisis (GFC), such influence of global risk aversion in emerging market economies can be analyzed.

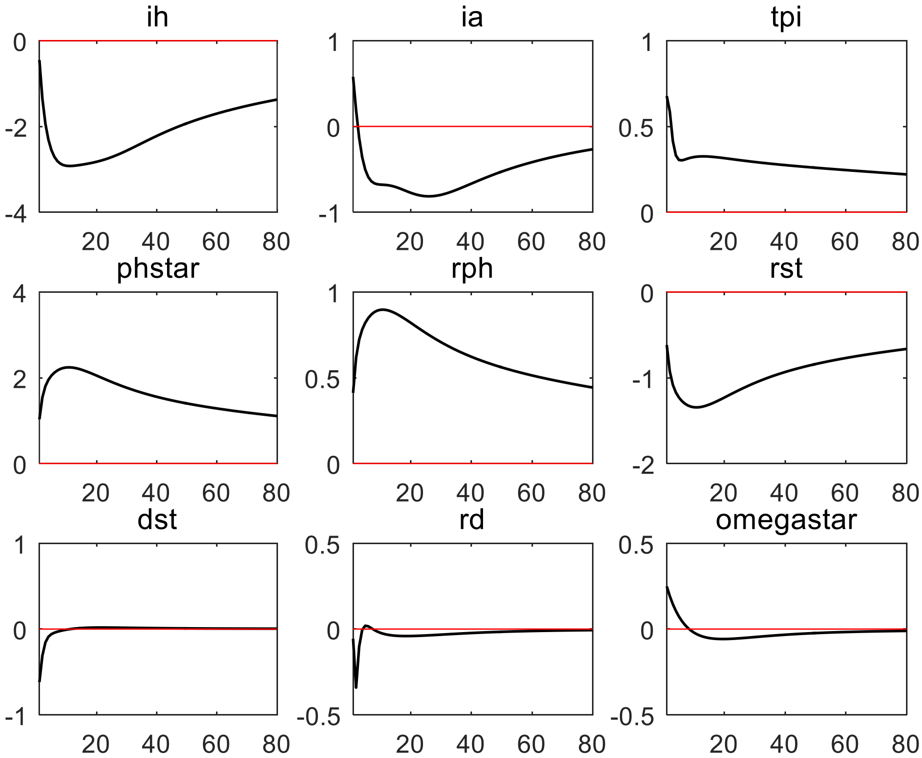
When the global interest rate increases, the real exchange rate can be appreciated because of the reduction in global interest rate spread based on uncovered interest rate parity channel. Furthermore, owing to the appreciation of exchange rate, the banks' balance sheet can be also deteriorated because appreciated exchange rate increases the bank's foreign debt. In addition, the domestic external finance premium increases and this works as credit constraint for domestic banks.

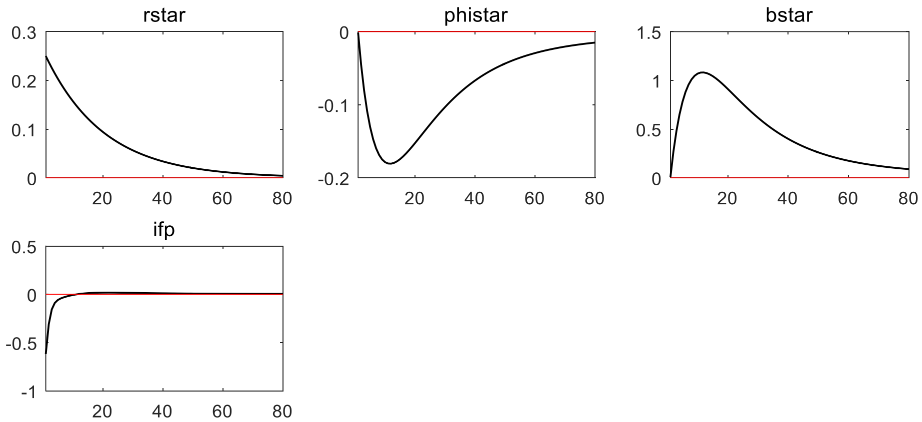
Figure 4.3: IRFs to a Global Interest Rate Shock




c
2
1
0
20 40 60 80
pmn
4
2
0
20 40 60 80
pi
2
1
0
20 40 60 80
rn
0.4
0.2
0
20 40 60 80
pm
2
1
0
20 40 60 80
efp
0.5
0
-0.5
20 40 60 80
lambda
5
0
-5
20 40 60 80
erk
0
-0.2
-0.4
20 40 60 80
phic
2
0
-2
20 40 60 80


f
2
0
-2
20 40 60 80
f1
2
0
-2
20 40 60 80
pistar
4
2
0
20 40 60 80
ym
0
-2
-4
20 40 60 80
mc
0
-1
-2
20 40 60 80
in
0.2
0
-0.2
20 40 60 80
ch
1
0
-1
20 40 60 80
ca
4
2
0
20 40 60 80
chstar
0
-2
-4
20 40 60 80


ih
ia
tpi
phstar
rph
rst
dst
rd
omegastar
20
40
60
80


rstar
phistar
bstar
ifp
20
40
60
80

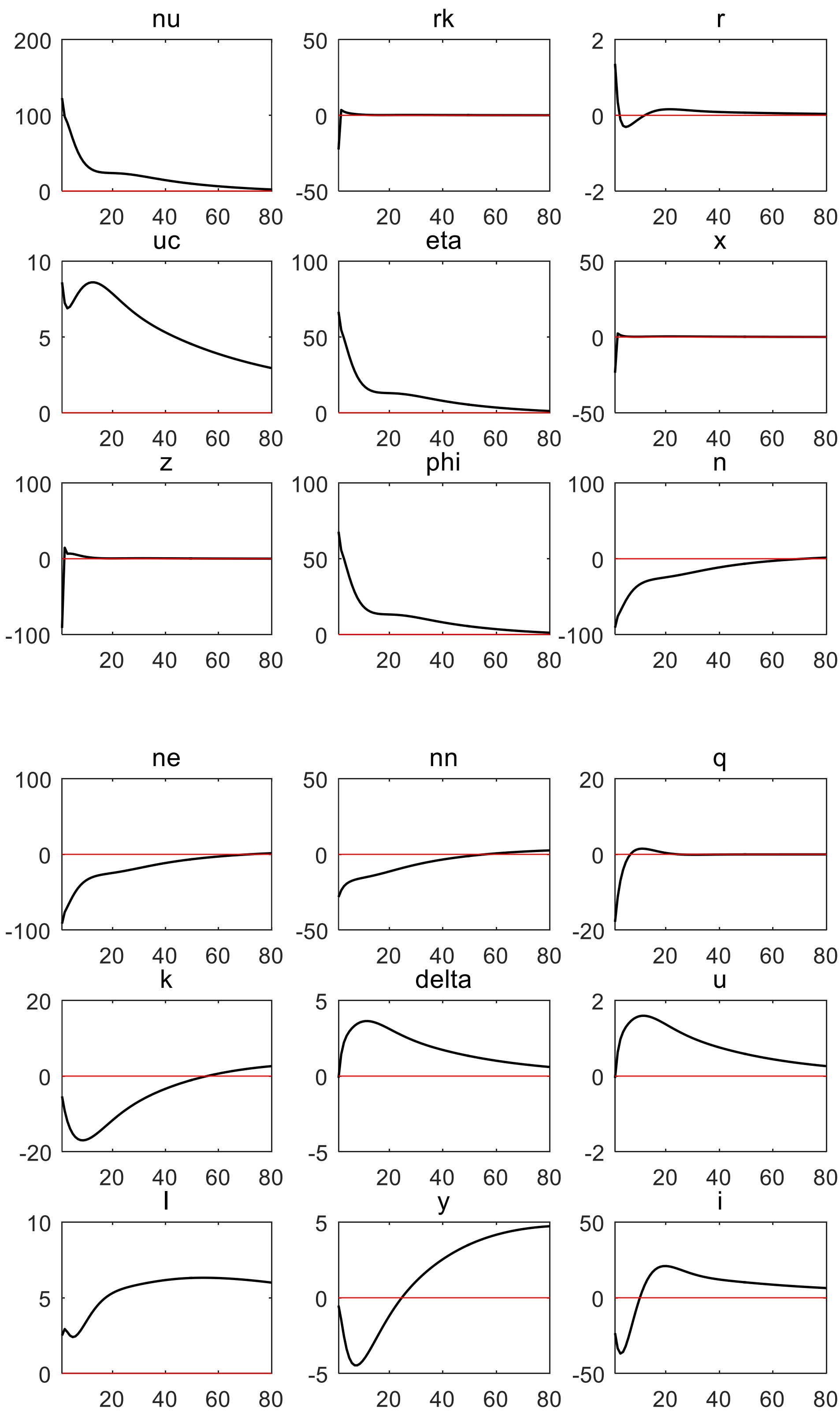
② Capital Quality Shock (-5%)

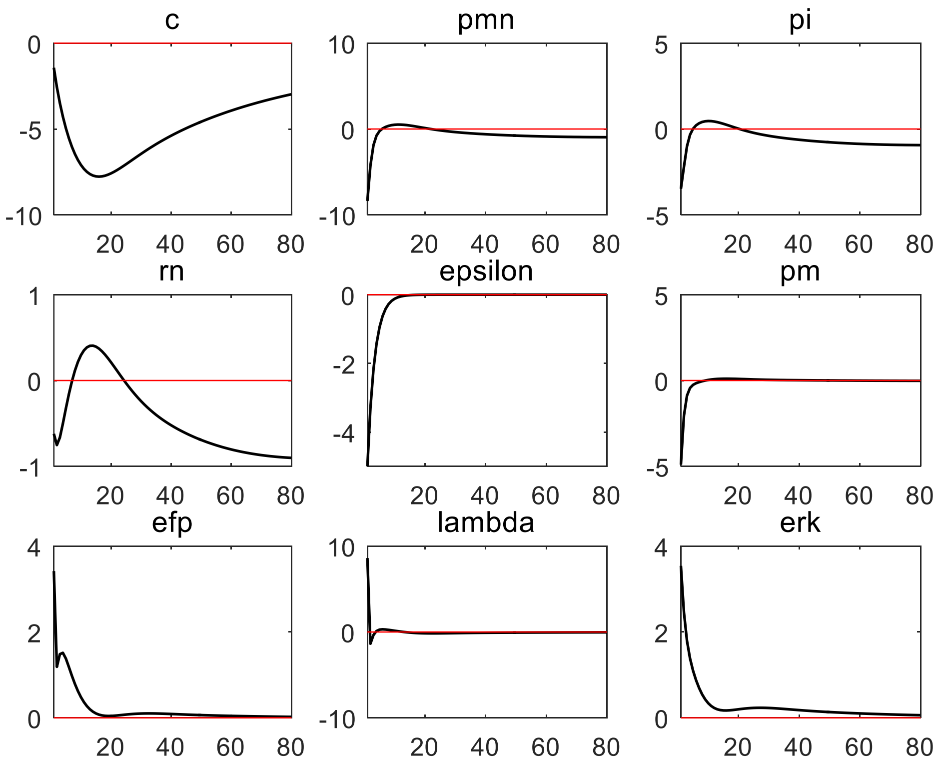
In order to capture a negative capital quality shock on bank's assets, it is assumed the banks face negative five percent shock in the value of their assets. This is similar to in chapter 3. In this model, a capital quality shock is represented as epsilon and autoregressive coefficient of the capital quality shock is assumed as 0.66 in AR(1) process following Gertler and Karadi (2010). It is also postulated that there is no credit and foreign exchange intervention in the simulation. ($\nu = 0$ and $\nu^* = 0$)

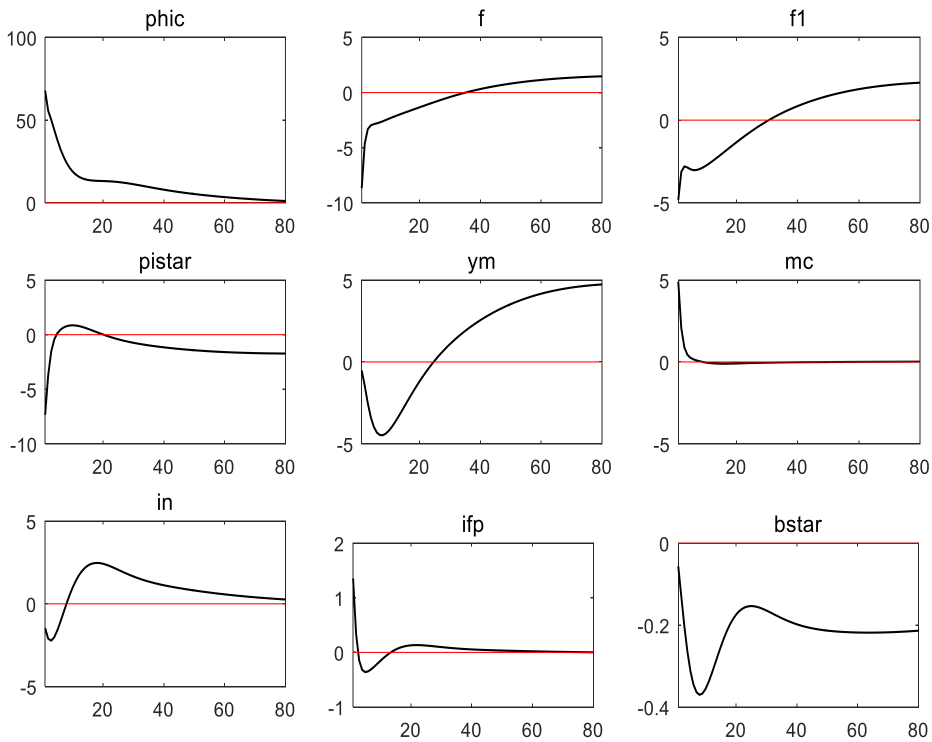
Similar to the transmission mechanism of negative financial shock in a closed economy, repercussion of negative five percent capital quality shock in a small open economy can be examined step by step. First, the first five percent drop in the bank's assets reduces the quantity of effective capital. Since then, this type of dropped effective capital reduces the values of bank's assets repeatedly. In the next stage, the lessened balance sheet of the banks cause the decline in asset value and investment based on the leverage. As a result of the reduced investment, output is also lessened finally.

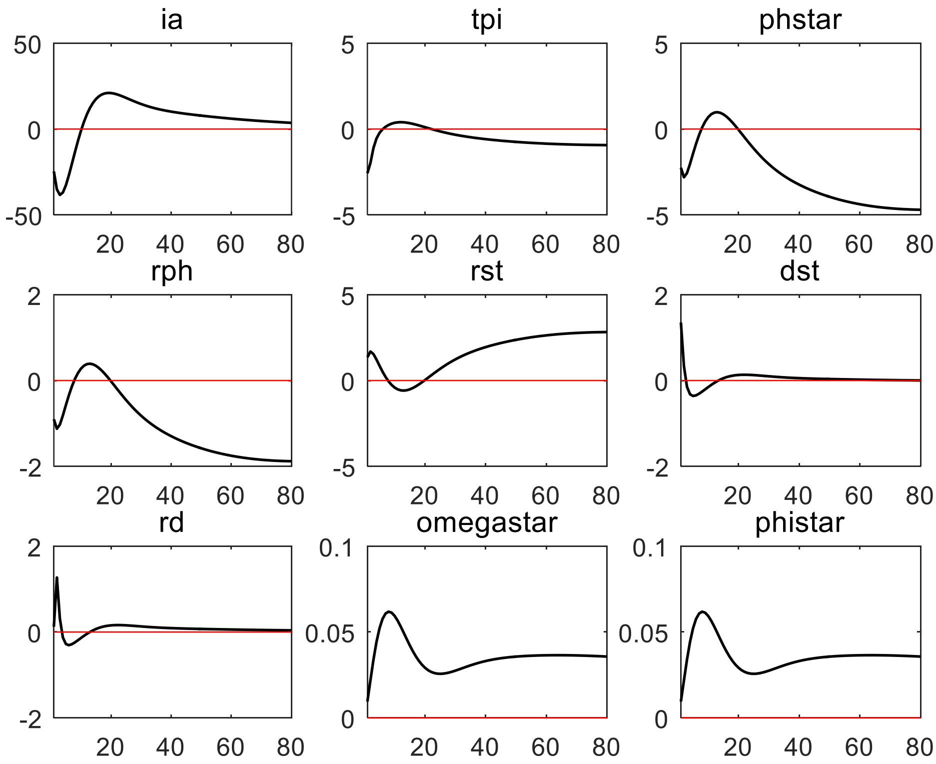
However, in this extended small open economy model, additional transmission channel is included. The negative five percent shock in the capital quality of the banks cause a steep appreciation of real exchange rate. Such influence also reduces international interest rate spread between domestic and global interest rate. Accordingly, resulted appreciation of real exchange rate can contribute to increasing import and decreasing export.

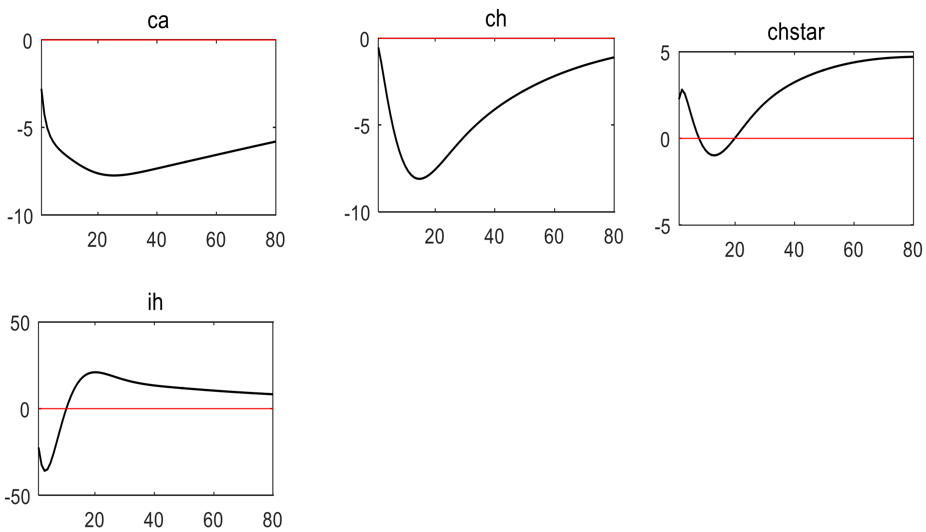
<u>Figure 4.4: IRFs to a Capital Quality Shock</u>




c
pmn
pi
rn
epsilon
pm
efp
lambda
erk


phic
f
f1
pistar
ym
mc
in
ifp
bstar


ia
50
0
-50
20 40 60 80
tpi
5
0
-5
20 40 60 80
phstar
5
0
-5
20 40 60 80
rph
2
0
-2
20 40 60 80
rst
5
0
-5
20 40 60 80
dst
2
0
-2
20 40 60 80
rd
2
0
-2
20 40 60 80
omegastar
0.1
0.05
0
20 40 60 80
phistar
0.1
0.05
0
20 40 60 80


ca
0
-5
-10
20 40 60 80
ch
0
-5
-10
20 40 60 80
chstar
5
0
-5
20 40 60 80
ih
50
0
-50
20 40 60 80

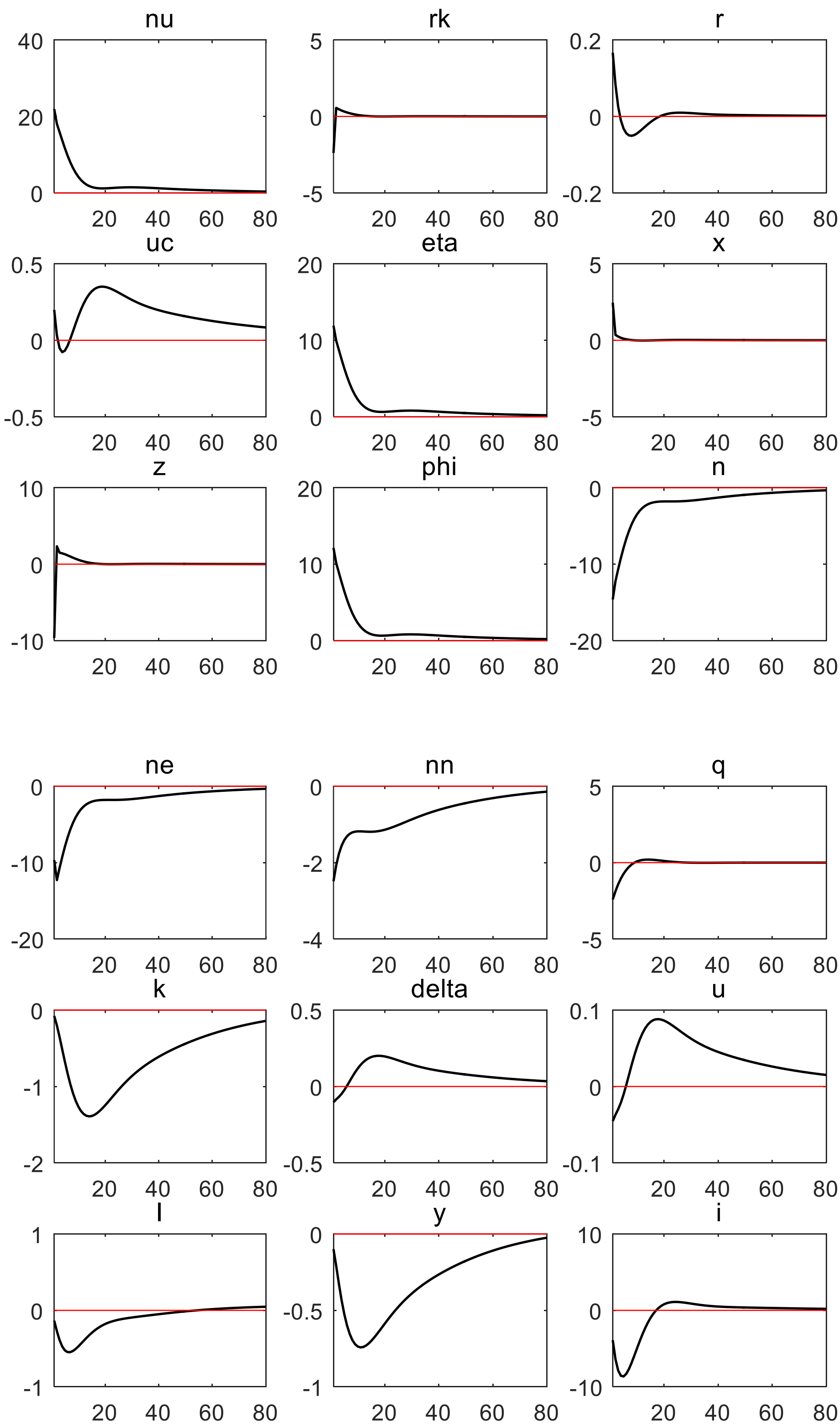
③ Bank Net Worth Shock (-5%)

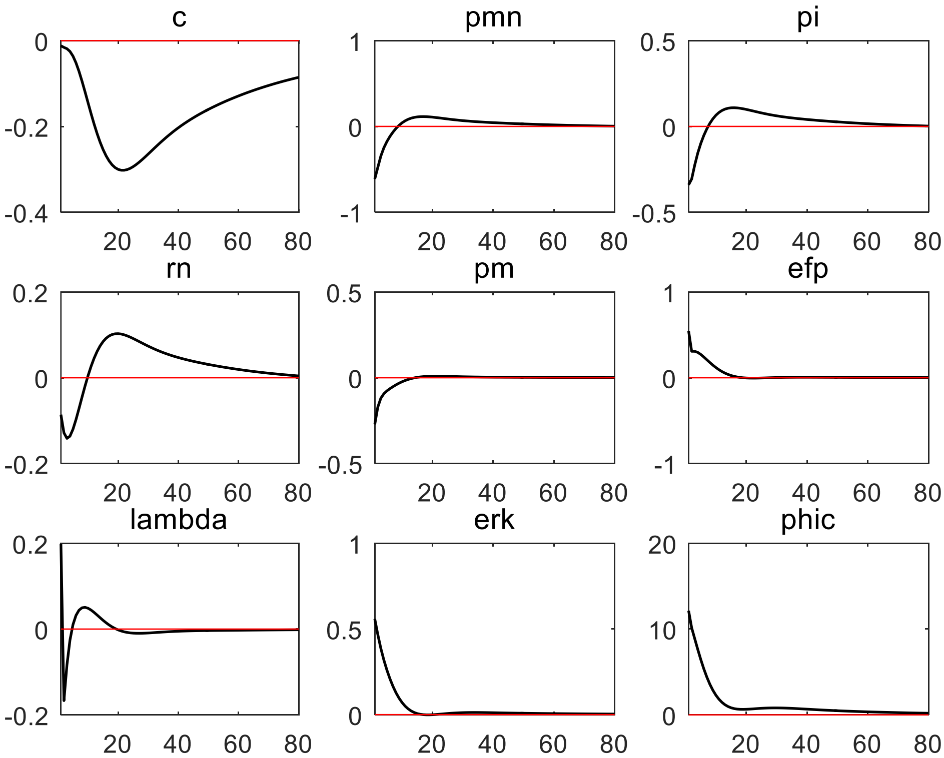
To understand the effect of negative shock to bank net worth, the situation is postulated banks face negative five percent shock in the bank net worth. Like the cases of previous shocks such as global interest rate and capital quality, there is underlying assumption the Central Bank does not conduct any intervention in the credit or the foreign exchange market. ($\nu = 0$ and $\nu^* = 0$)

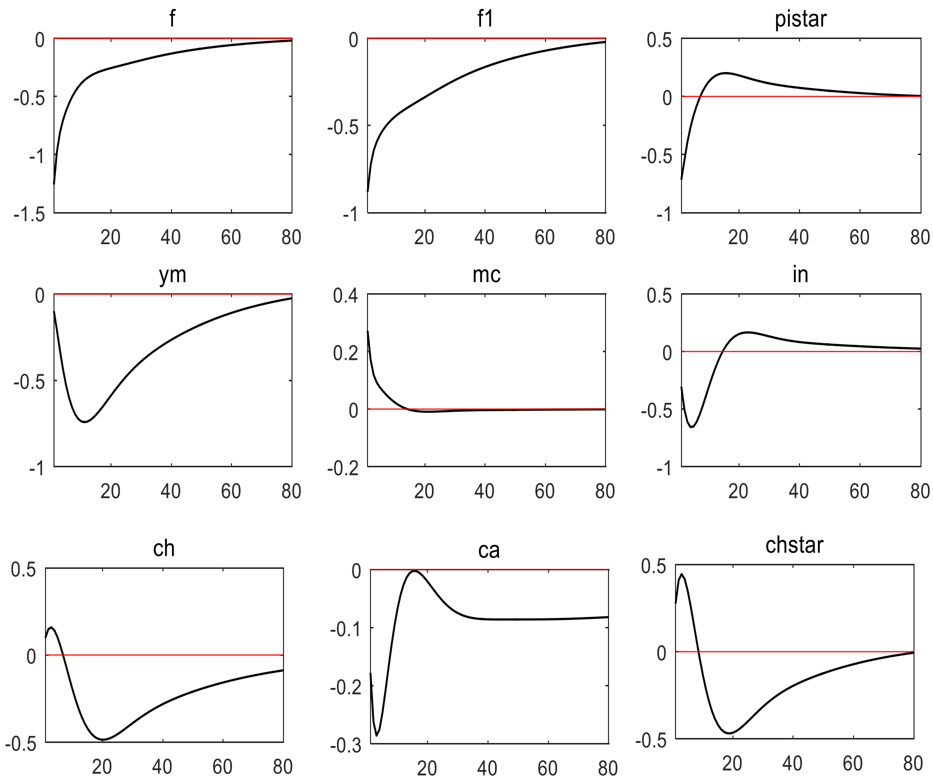
The transmission mechanism of negative bank net worth shock in a small open emerging economy seems to be similar to that transmission of closed economy. In response to negative five percent shock to a bank net worth, the risk premium increases immediately. Furthermore, the capital value also declines. As a result, the investment and output in a real economy are also deteriorated. Inflation also declines immediately.

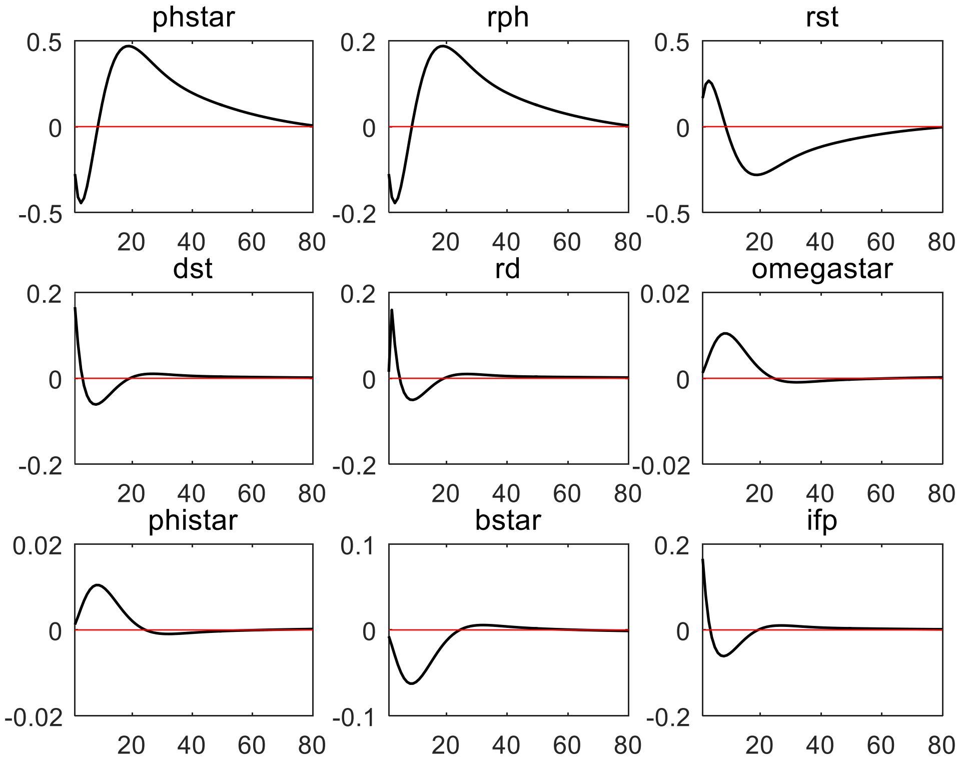
In broad outlines, the economic effect of negative five percent bank net worth shock seems weaker than the impact of same degree of capital quality shock in a small open emerging economy. This result seems to be consistent to the previous crisis simulation carried out in chapter 3 under a closed economy environment.

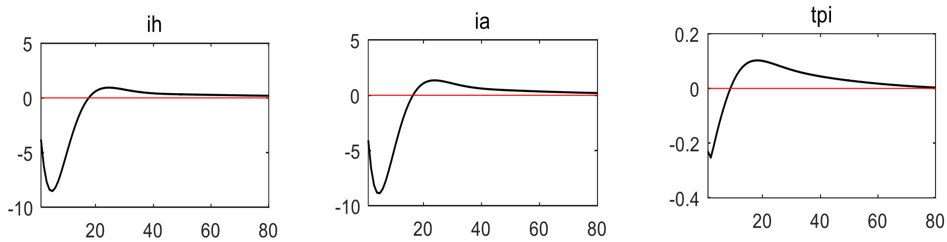
Figure 4.5: IRFs to a Bank Net Worth Shock




c
pmn
pi
rn
pm
efp
lambda
erk
phic


f
f1
pistar
ym
mc
in
ch
ca
chstar


phstar
rph
rst
dst
rd
omegastar
phistar
bstar
ifp
0.5
0
-0.5
0.2
0
-0.2
0.02
0
-0.02
0.1
0
-0.1
20
40
60
80


ih
ia
tpi
5
0
-5
-10
0.2
0
-0.2
-0.4
20
40
60
80

(Credit and Foreign Exchange Policy Simulation)

It is postulated that the Central bank in a small open economy conducts two sorts of unconventional monetary policies which are the interventions in the domestic credit market and the foreign exchange market. First of all, for the intervention in domestic credit market, it is postulated the Central Bank is able to directly lend to non-financial firms in response to increasing risk premium. On the other hand, when it comes to such intervention in the foreign exchange market, the Central Bank manages some amount of foreign reserves to influence on the real exchange rate based on uncovered interest rate parity (UIP) condition.

With regard to feedback rule of policy reaction, there are two types of feedback parameters (ν and ν^*). The feedback parameter (ν) reflects the intensity of domestic credit market intervention. On the other hand, another feedback parameter (ν^*) stands for strength of the intervention in the foreign exchange market. Simulations are implemented for three values of feedback parameters for the interventions of credit market and the foreign exchange market: 10, 50, and 100. When ν or ν^* is 10, it is closer to a real life. On the other hand, when ν or ν^* is 50, it means there is an aggressive intervention in credit or foreign exchange market. Specific state which ν or ν^* is equal to 100 represents the economy is near to the optimal situation.

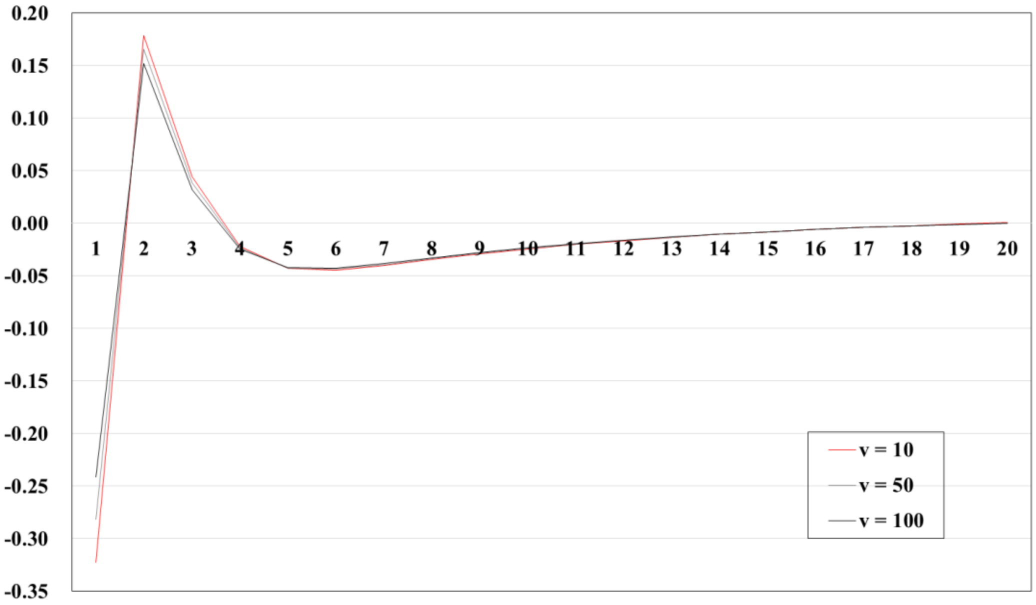
First, figure (4.6) and (4.7) show performances of the intervention in domestic credit market or foreign exchange market respectively, in response to global interest rate shock (+25bp). The intervention in domestic credit market for global interest rate shock makes the crisis less severe. Specifically, the domestic credit market intervention is helpful in reducing the increase of risk premium. However, inflation dynamics of output do not change drastically despite the intervention in domestic credit market. Meanwhile, the foreign exchange market intervention can be more effective than the intervention in domestic credit market. Figure (4.7) shows the intervention through foreign exchange market is contributed to considerably moderate negative impacts on external finance premium, output, inflation, and bank net worth.

Next, figure (4.8) and (4.9) show performances of the intervention in domestic credit or foreign exchange market, respectively, for capital quality shock (-5%). The credit market intervention by the Central Bank for capital quality shock also makes the crisis less severe like the case of global interest rate shock. According to figure (4.8), it proves that the intervention in domestic credit market is helpful in reducing the increasing risk premium and moderating output fluctuation. On the contrary, the influence of the credit market intervention on inflation seems trivial. Meanwhile, figure (4.9) shows, although the intervention in foreign exchange market cannot affect the increase in external finance premium, it can make considerable contribution to make the crisis less severe for both output and inflation.

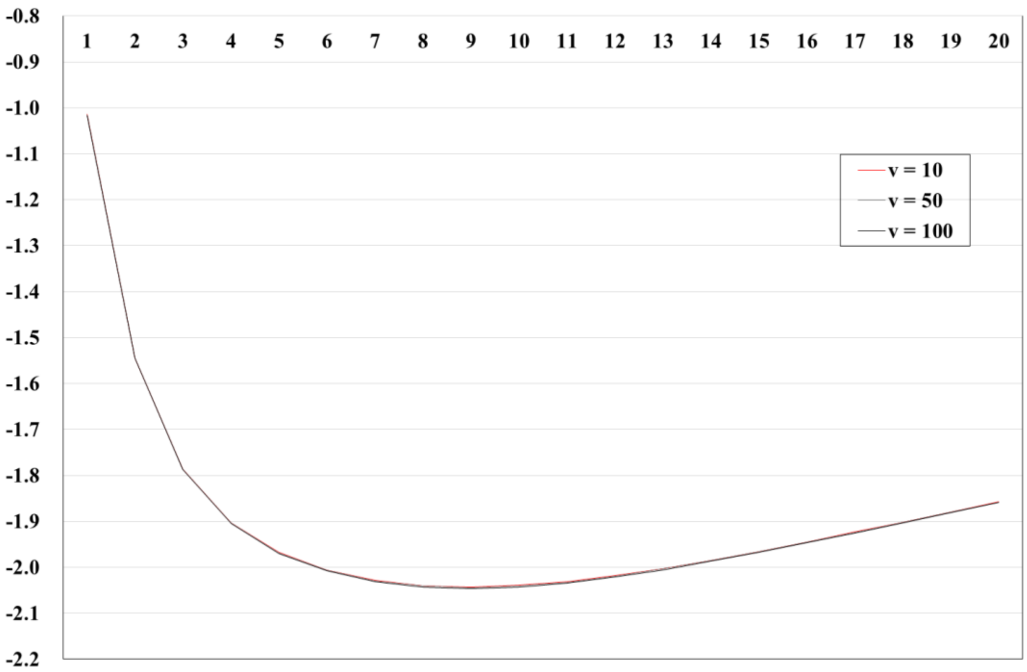
Finally, figure (4.10) and (4.11) show performances of intervention in domestic credit and foreign exchange market, respectively, with respect to bank net worth shock (-5%). Figure (4.10) shows that similar to capital quality shock, the credit market intervention for bank net worth shock makes the crisis less severe. In other words, the credit intervention contributes to reduce increasing risk premium and moderate fluctuations of output and inflation. However, figure (4.11) shows the impact of the foreign exchange market intervention on fluctuation of output and inflation is very insignificant.

Figure 4.6: IRFs to a Global Interest Rate Shock under Credit Policy

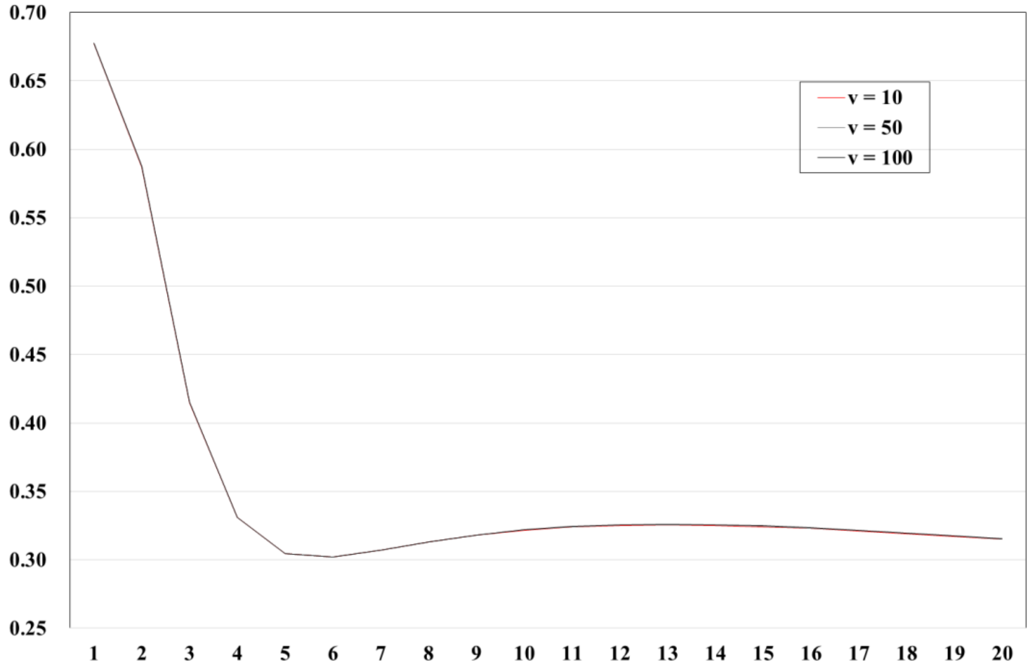
External Finance Premium (Spread)



Output



Inflation



Bank Net Worth (Bank Capital)

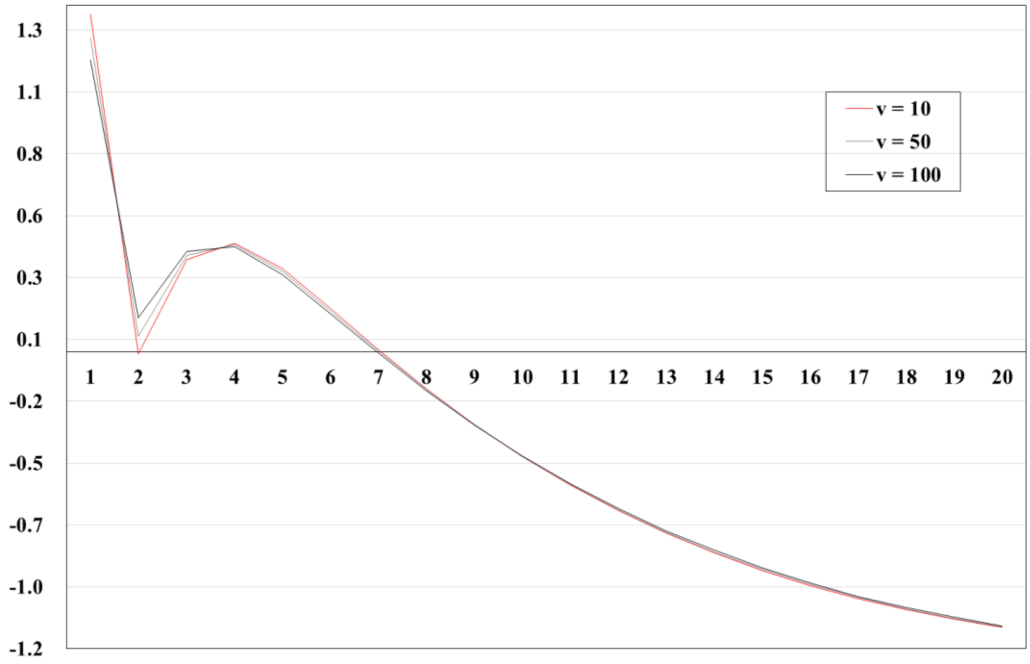
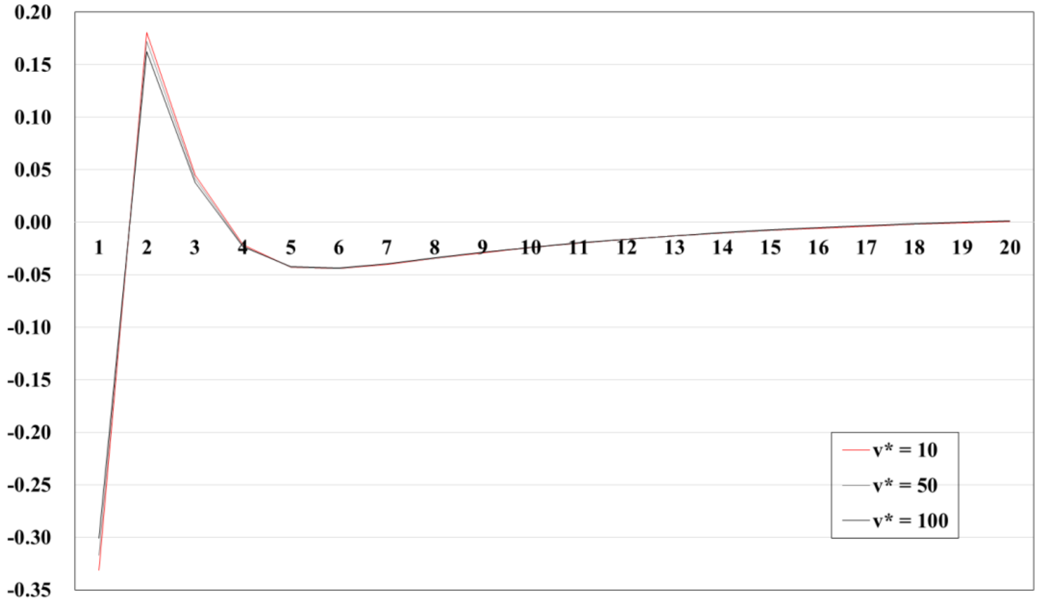
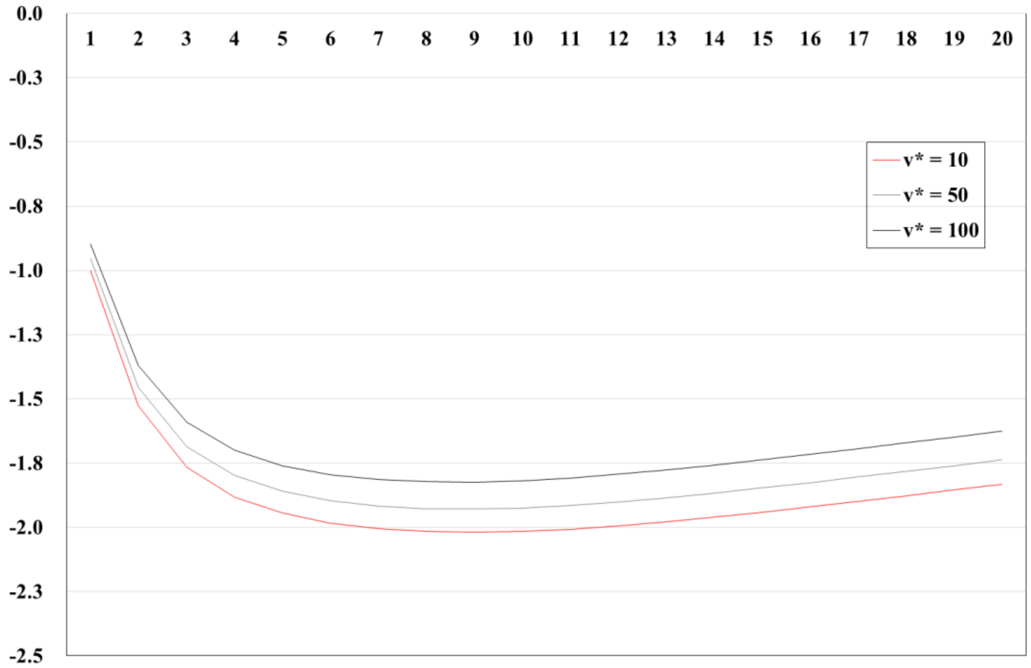


Figure 4.7: IRFs to a Global Interest Rate Shock under FX Policy

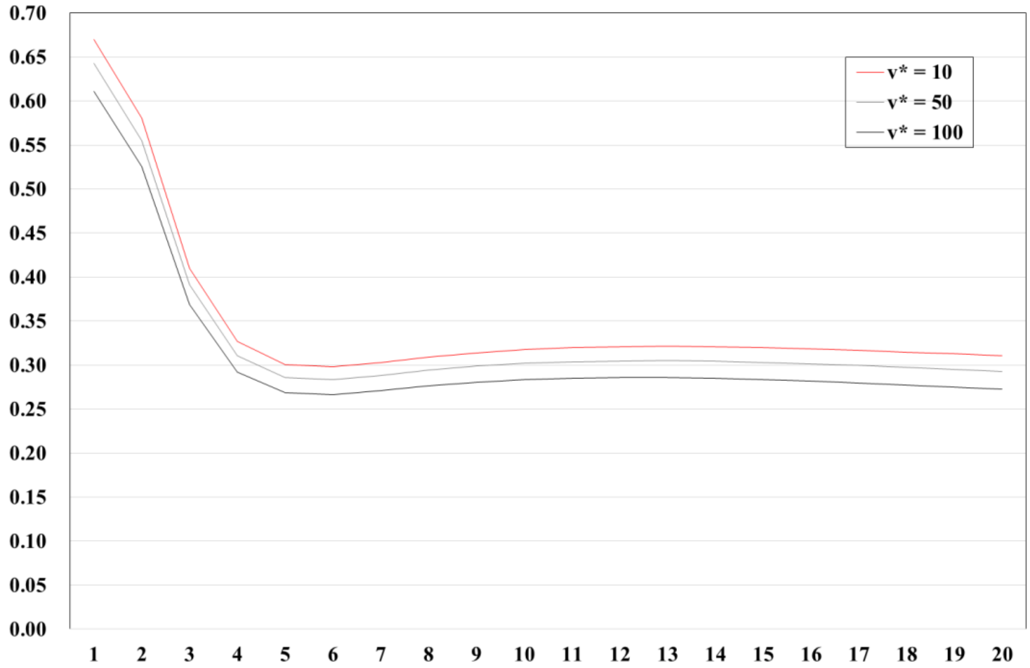
External Finance Premium (Spread)



Output



Inflation



Bank Net Worth (Bank Capital)

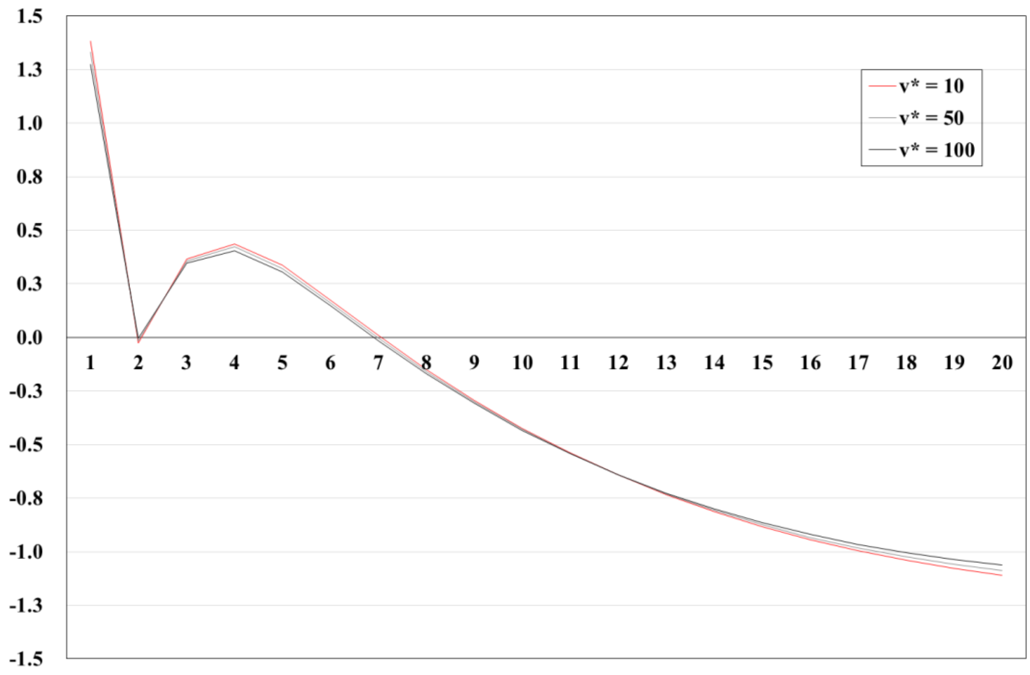
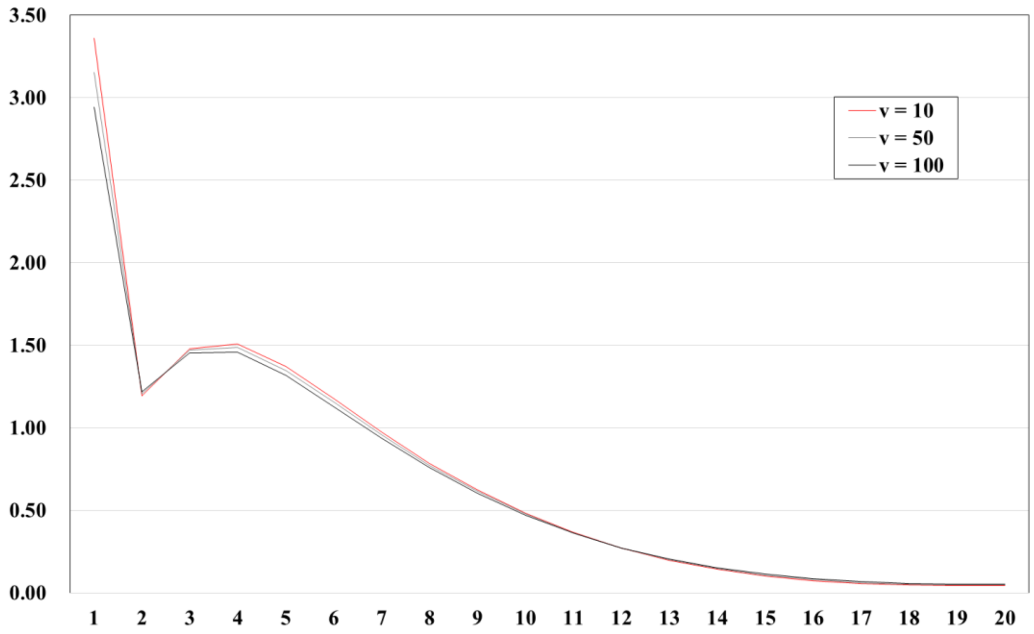
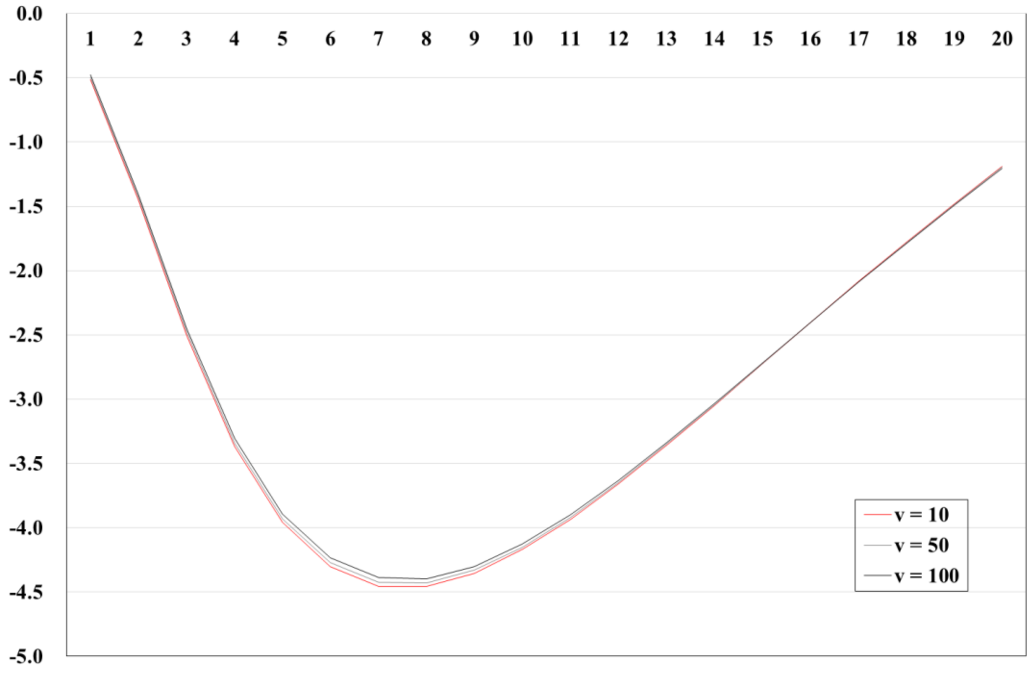


Figure 4.8: IRFs to a Capital Quality Shock under Credit Policy

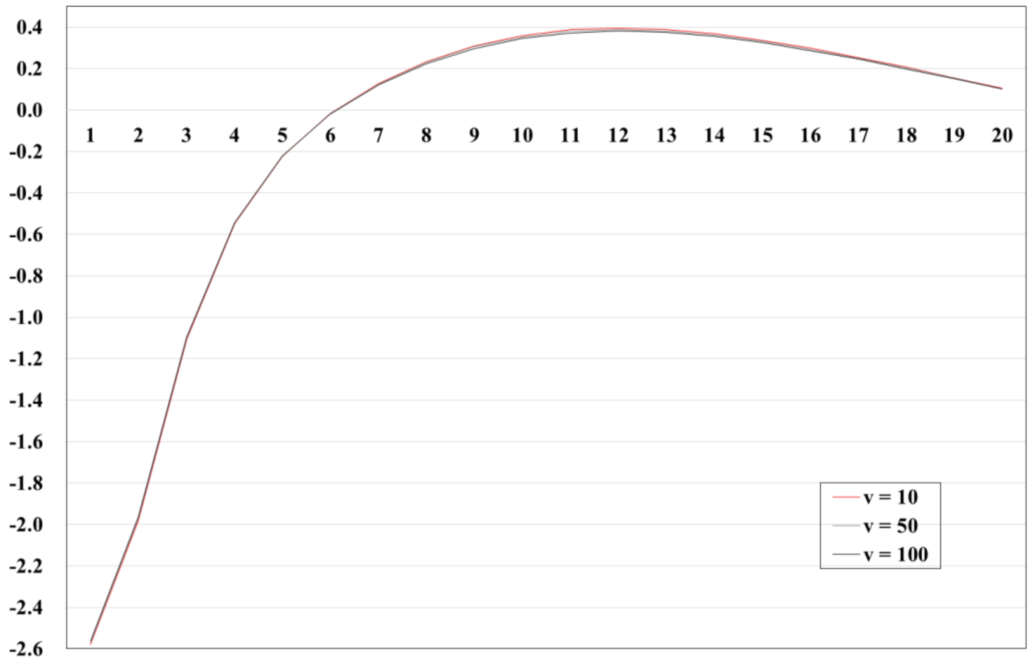
External Finance Premium (Spread)



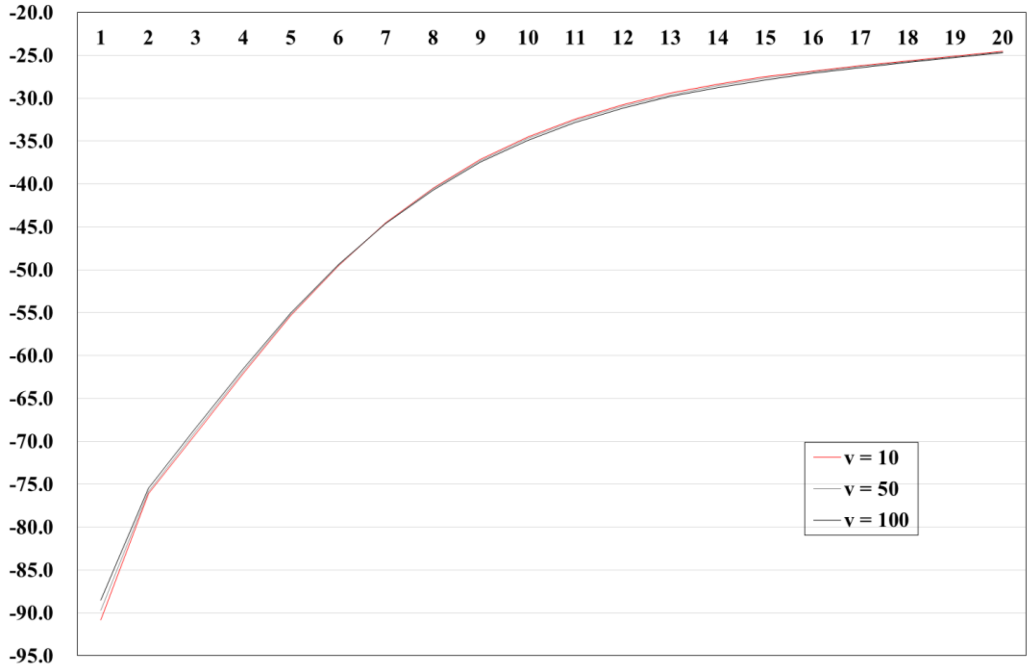
Output



Inflation

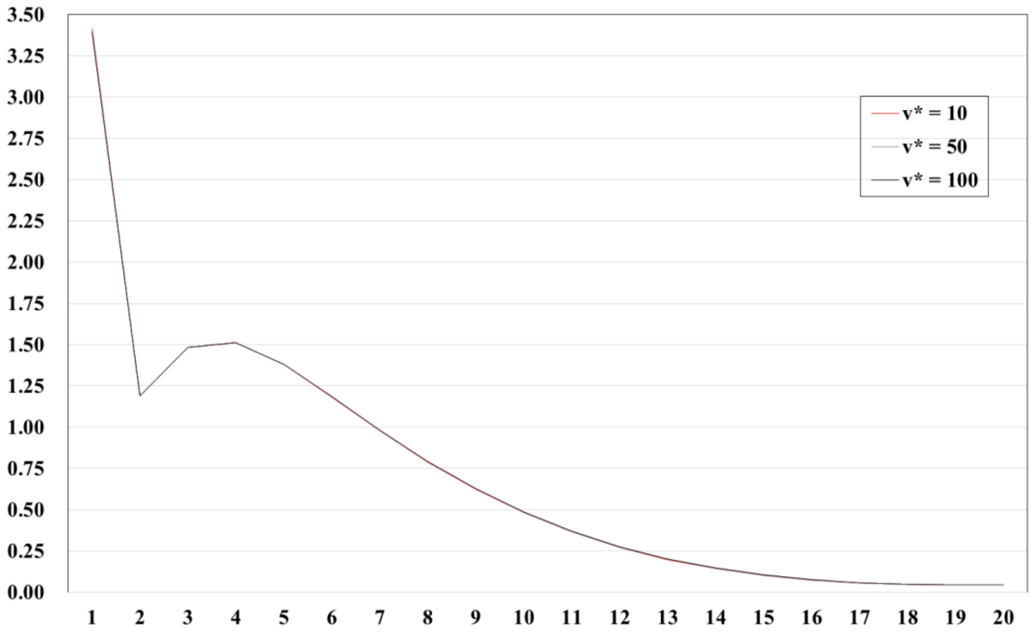


Bank Net Worth (Bank Capital)

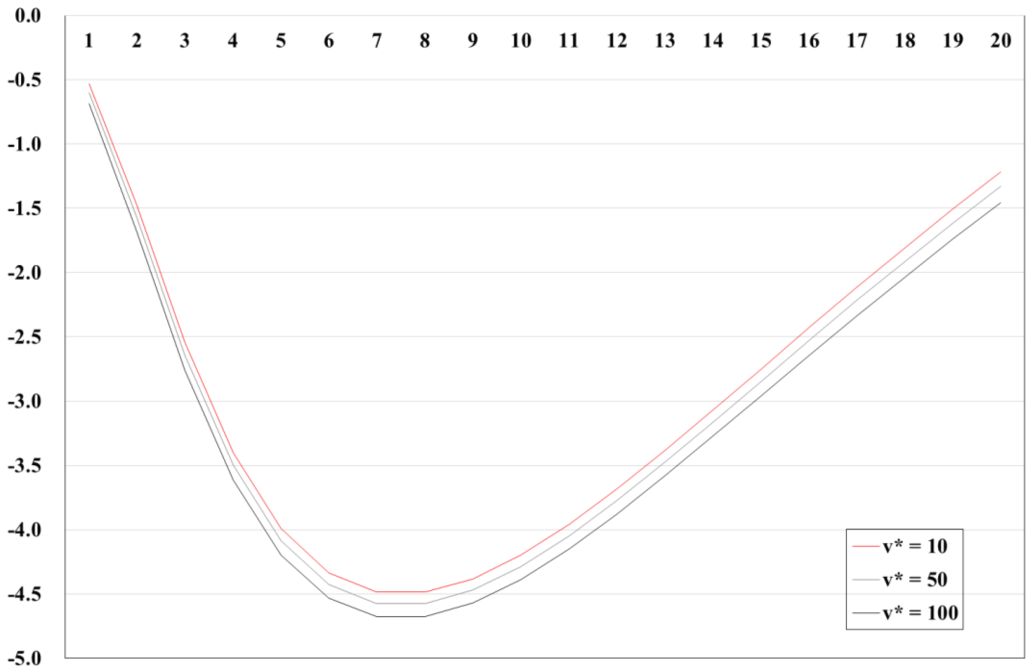


<u>Figure 4.9: IRFs to a Capital Quality Shock under FX Policy</u>

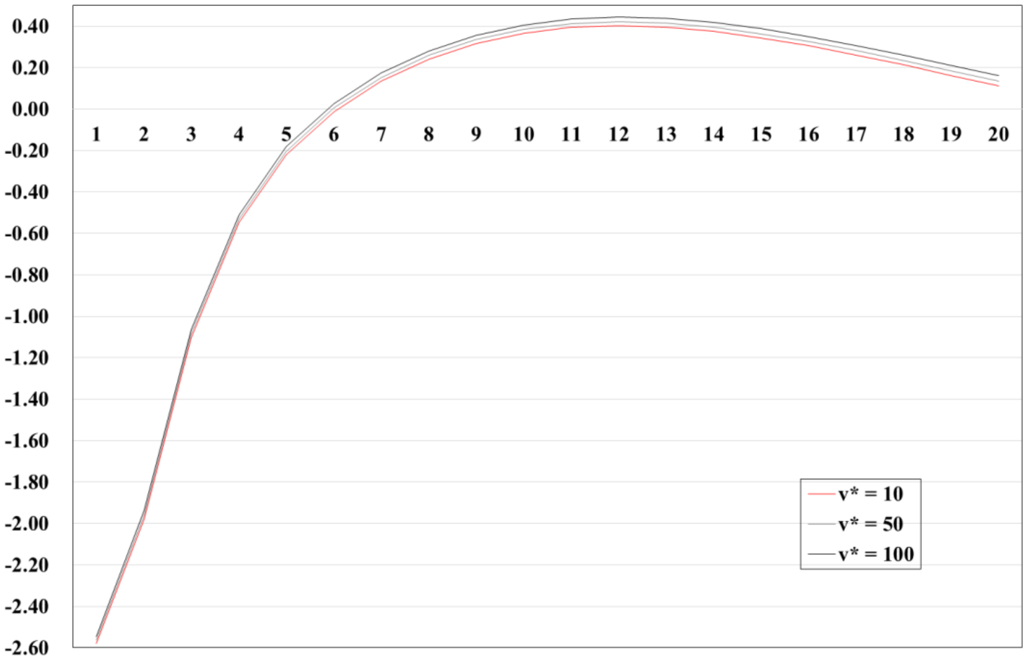
<u>External Finance Premium (Spread)</u>



<u>Output</u>



Inflation



Bank Net Worth (Bank Capital)

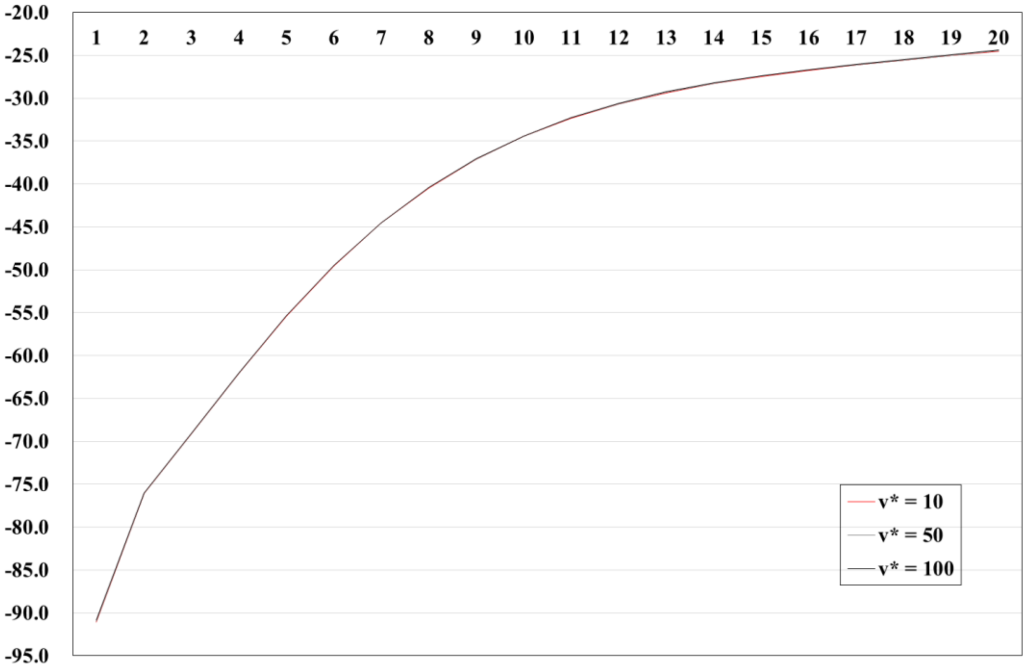
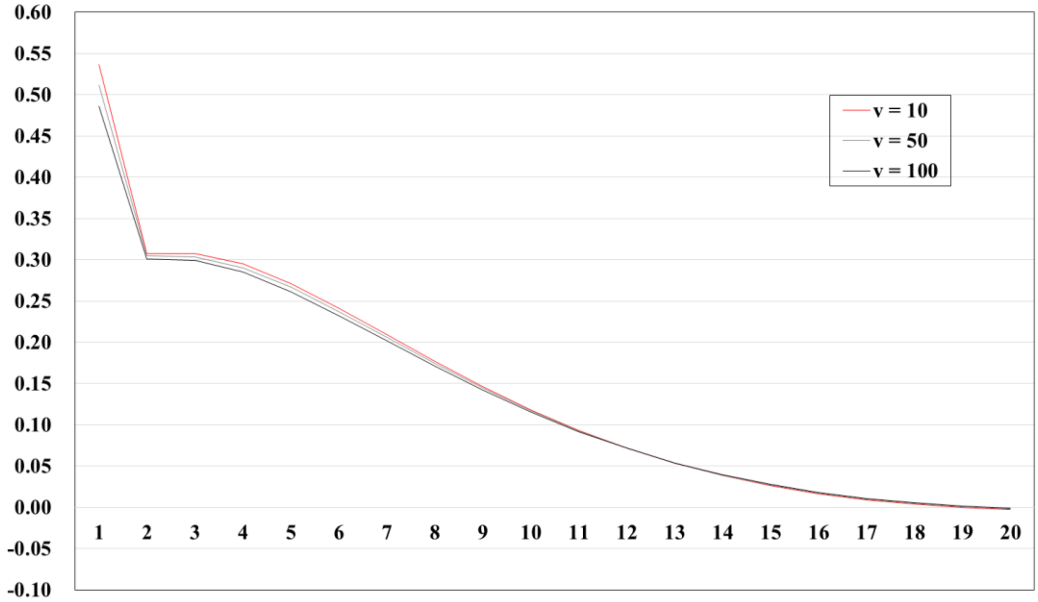
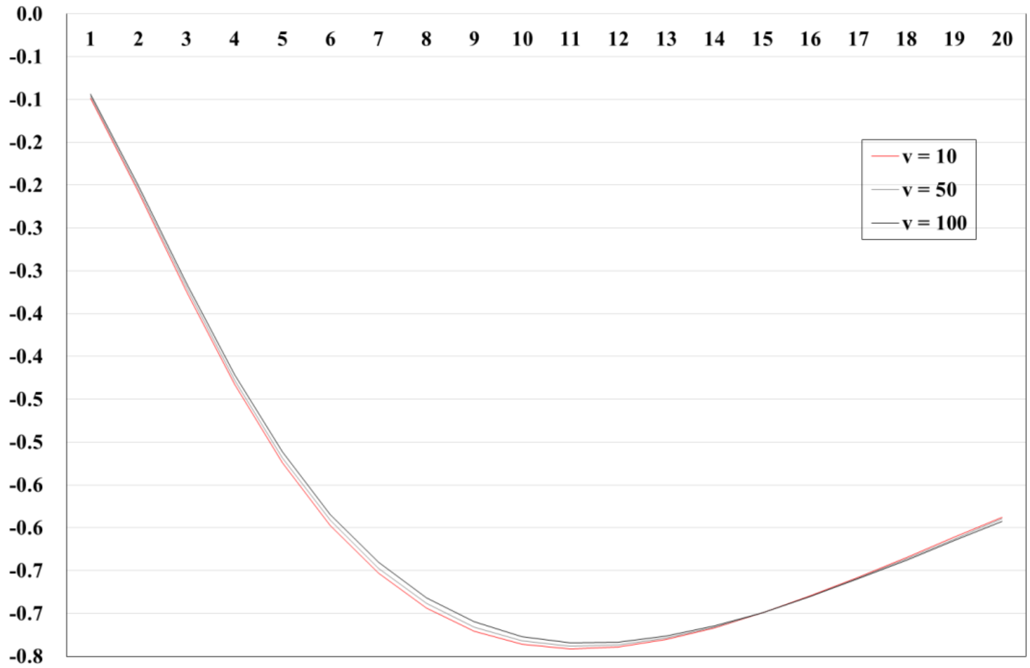


Figure 4.10: IRFs to a Bank Net Worth Shock under Credit Policy

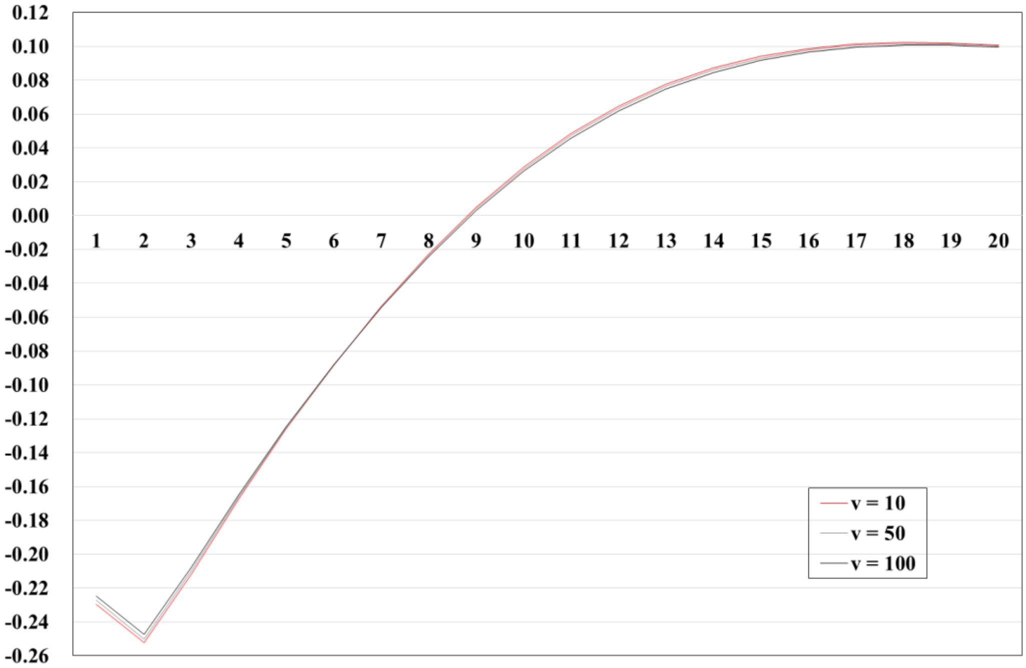
External Finance Premium (Spread)



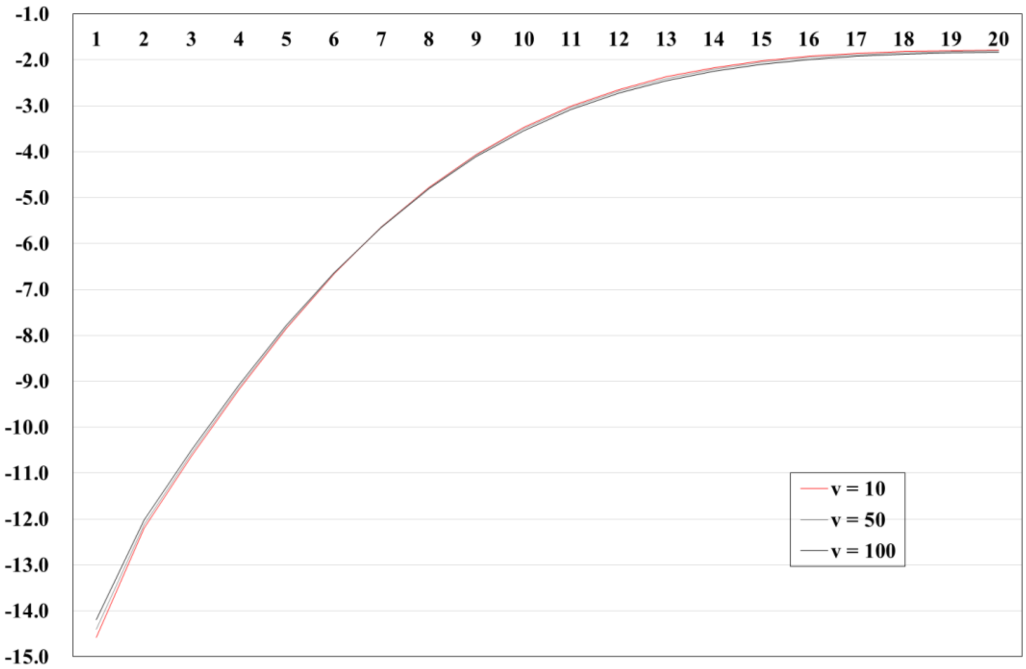
Output



Inflation

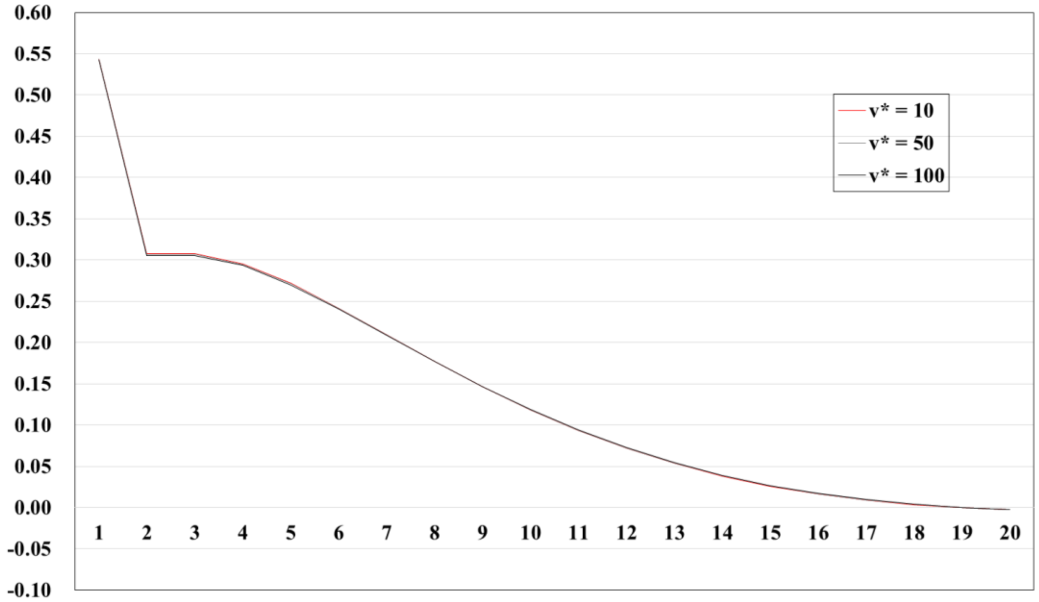


Bank Net Worth (Bank Capital)

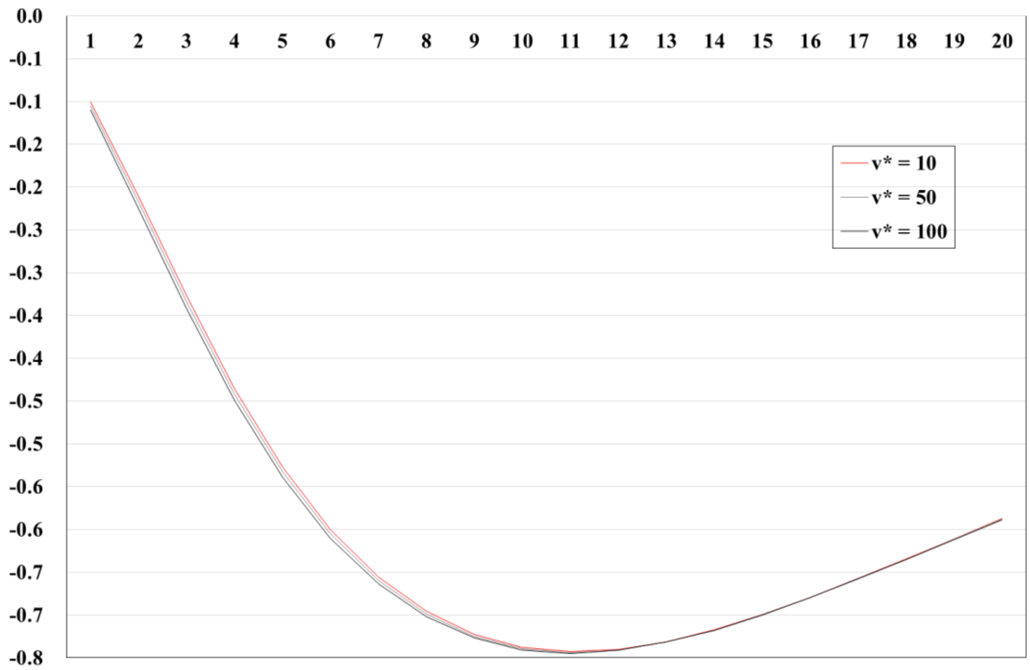


<u>Figure 4.11: IRFs to a Bank Net Worth Shock under FX Policy</u>

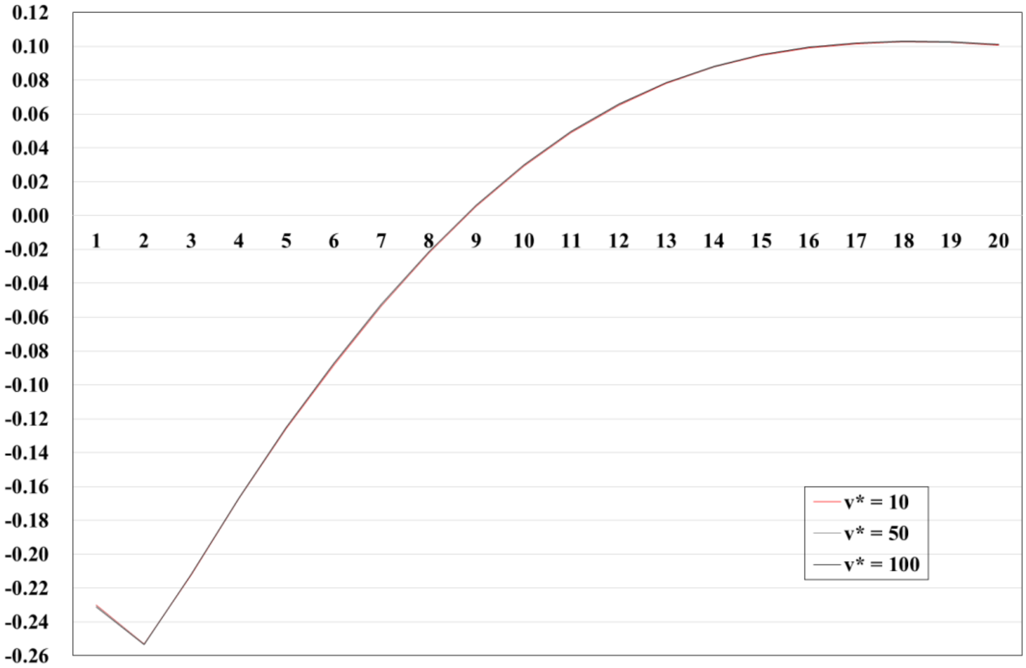
<u>External Finance Premium (Spread)</u>



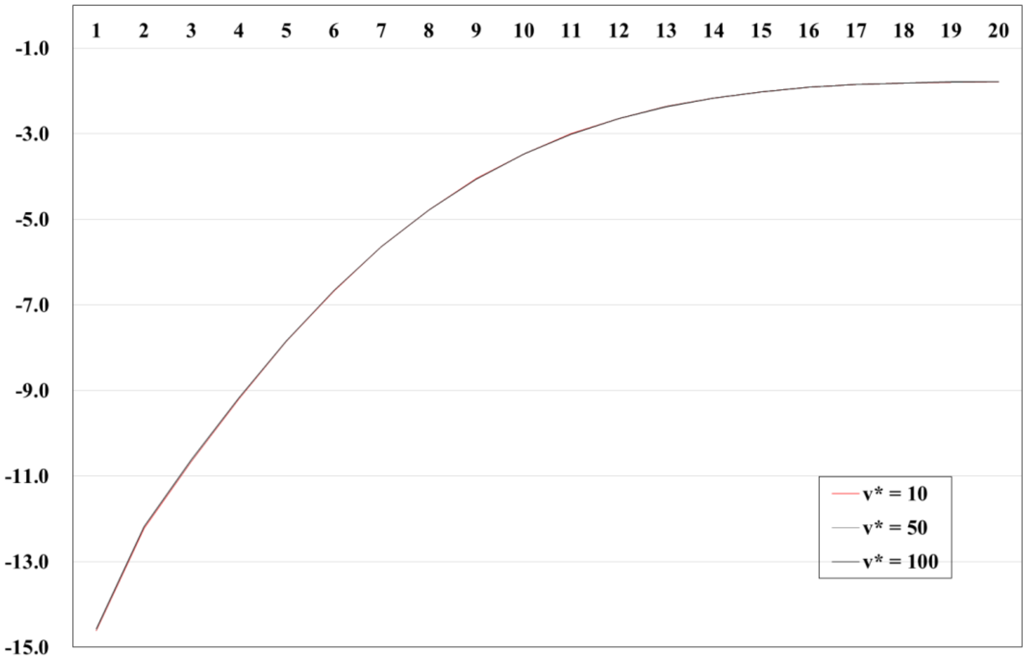
<u>Output</u>



Inflation



Bank Net Worth (Bank Capital)



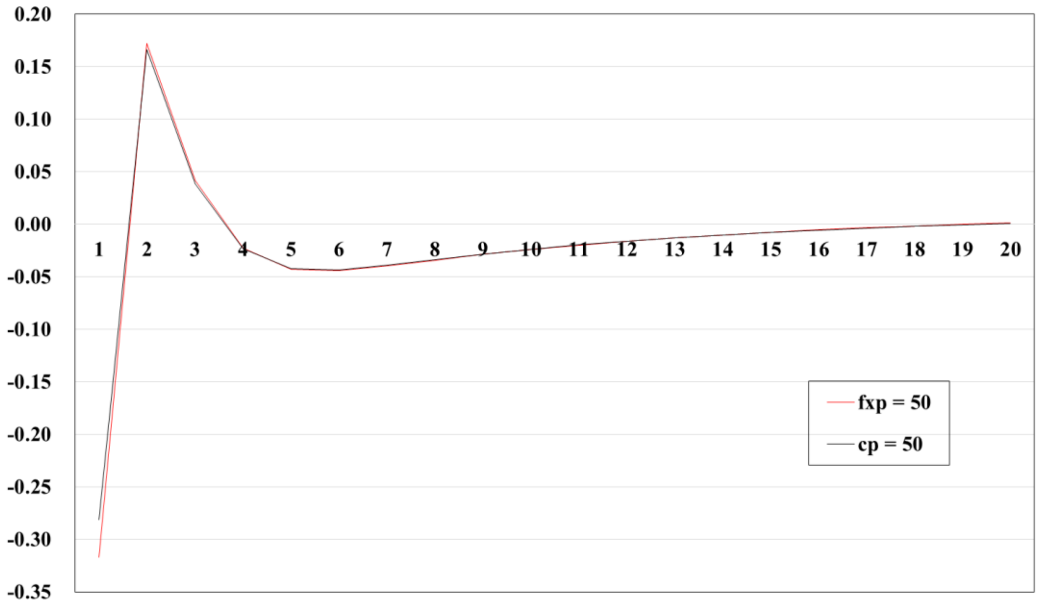
(Comparison for Credit and Foreign Exchange Policy)

First, figure (4.12) shows comparative results between credit and foreign exchange policy for global interest rate shock. It seems that the foreign exchange market intervention can be more effective than corresponding intervention in domestic credit market. Even though the intervention in the market of foreign exchange is less telling in directly affecting some change of domestic external finance premium, the foreign exchange intervention policy can be contributed to prevent an export from sharp decline through the reduced appreciation of exchange rate. Hence, such foreign exchange intervention policy can be supportive in preventing a sharp drop in output for global interest rate shock which is applied to emerging market economies during a crisis in terms of global risk aversion.

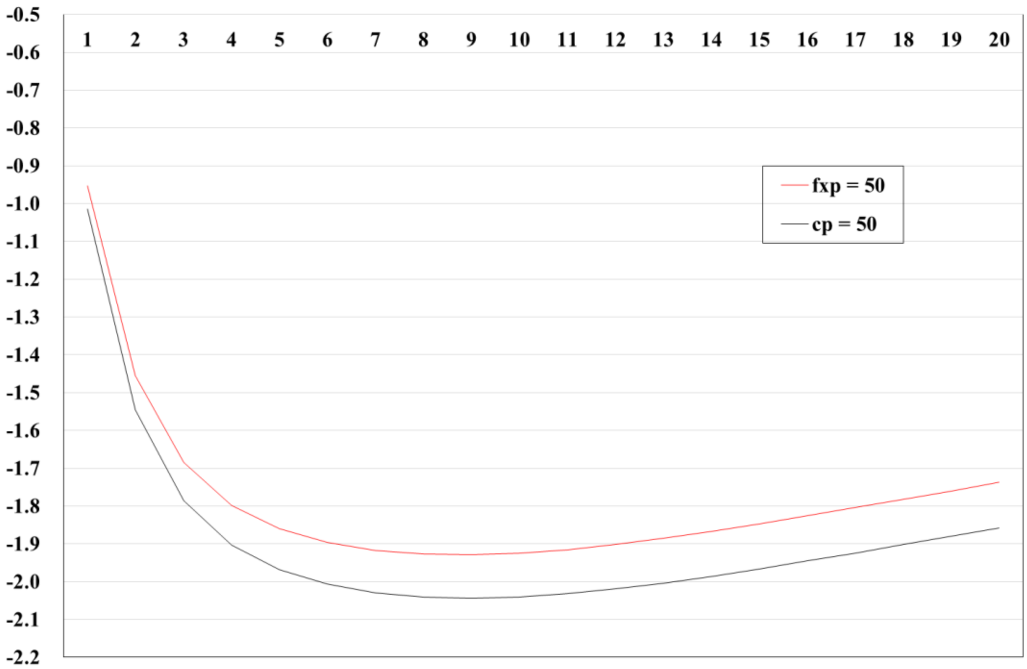
On the other hand, figure (4.13) and (4.14) demonstrate comparative results of credit and foreign exchange policy for negative capital quality and negative bank net worth shock. It is regarded as the policy effectiveness of intervention in domestic credit market is slightly better than the intervention in market of foreign exchange in moderating the influences of negative shocks. When negative capital quality or bank capital shock arises in the domestic banking sector, the policy effectiveness of the foreign exchange market intervention is restricted because such foreign exchange market intervention cannot affect effectively increasing domestic risk premium. Hence, it seems that the intervention in domestic credit market is more successful than the foreign exchange market intervention in reaction to capital quality shock or bank net worth shock occurred domestically.

Figure 4.12: Comparison of IRFs to a Global Interest Rate Shock under Credit and FX Policy

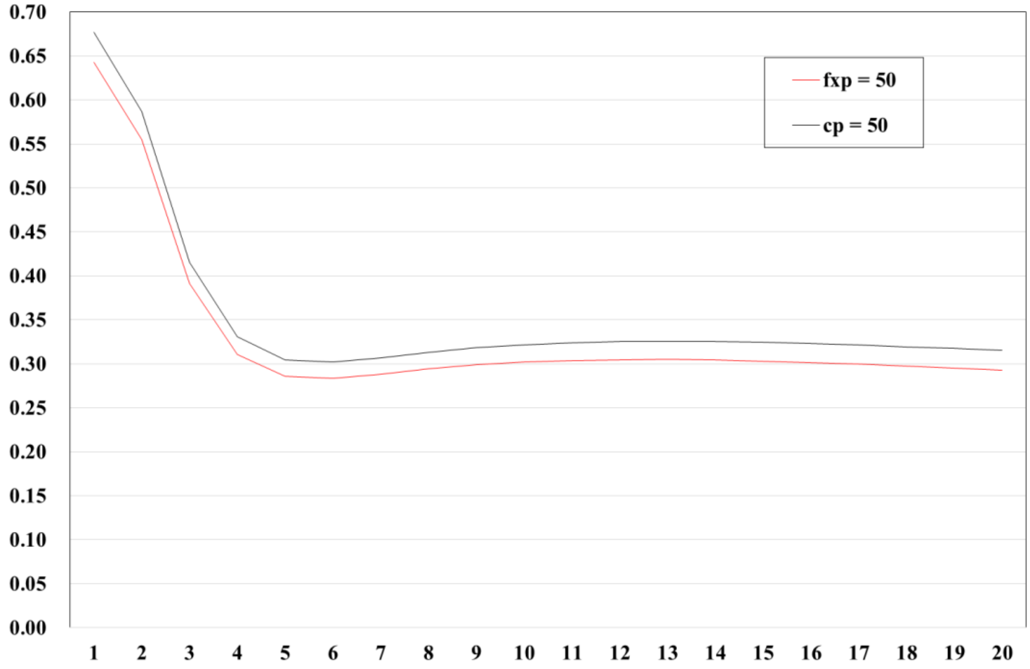
External Finance Premium (Spread)



Output



Inflation



Bank Net Worth (Bank Capital)

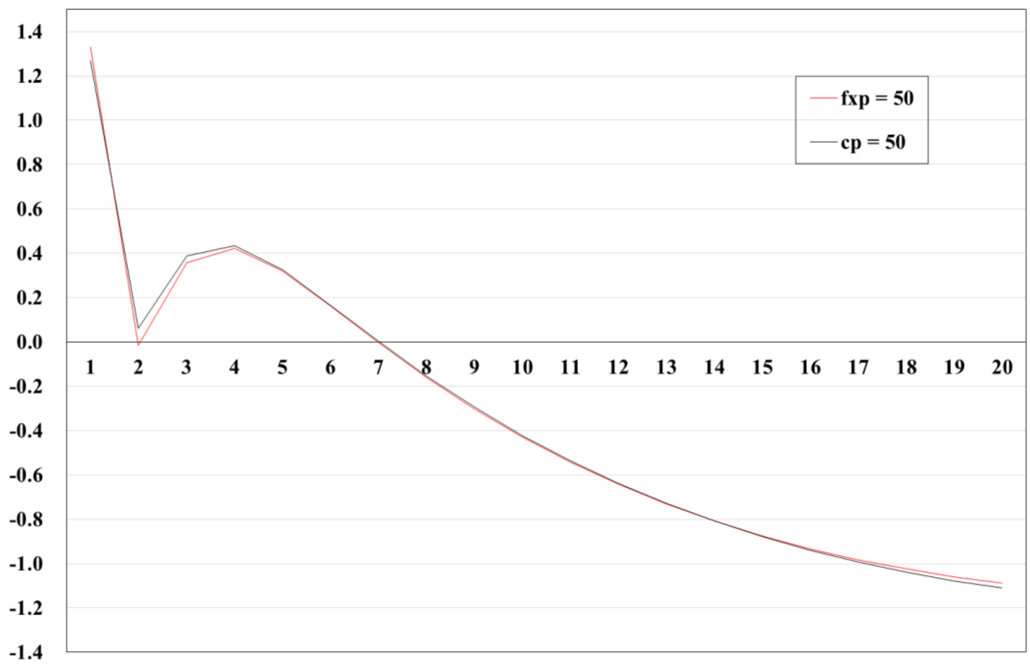
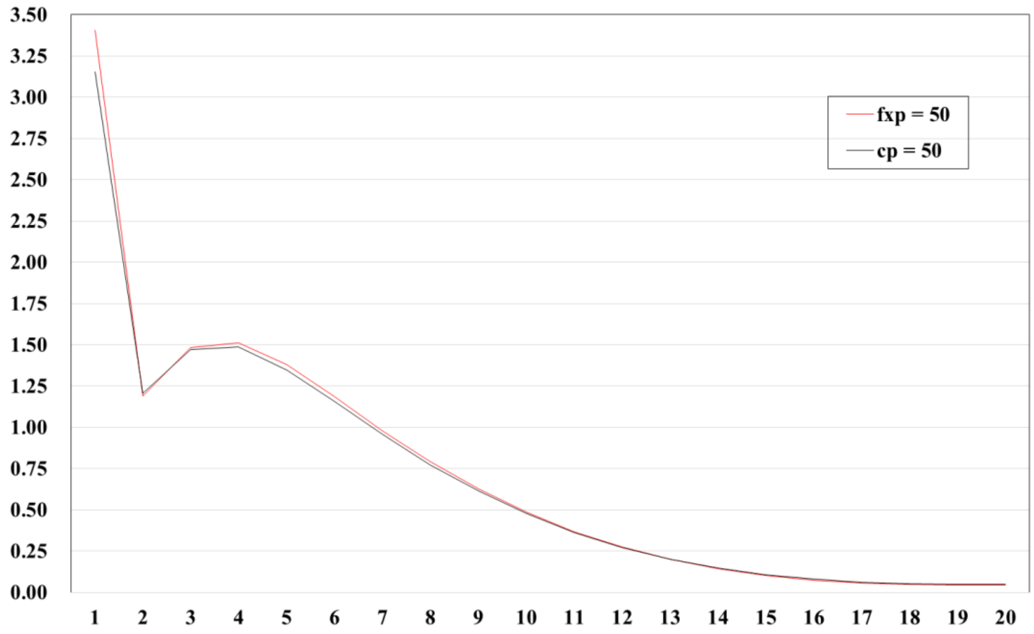
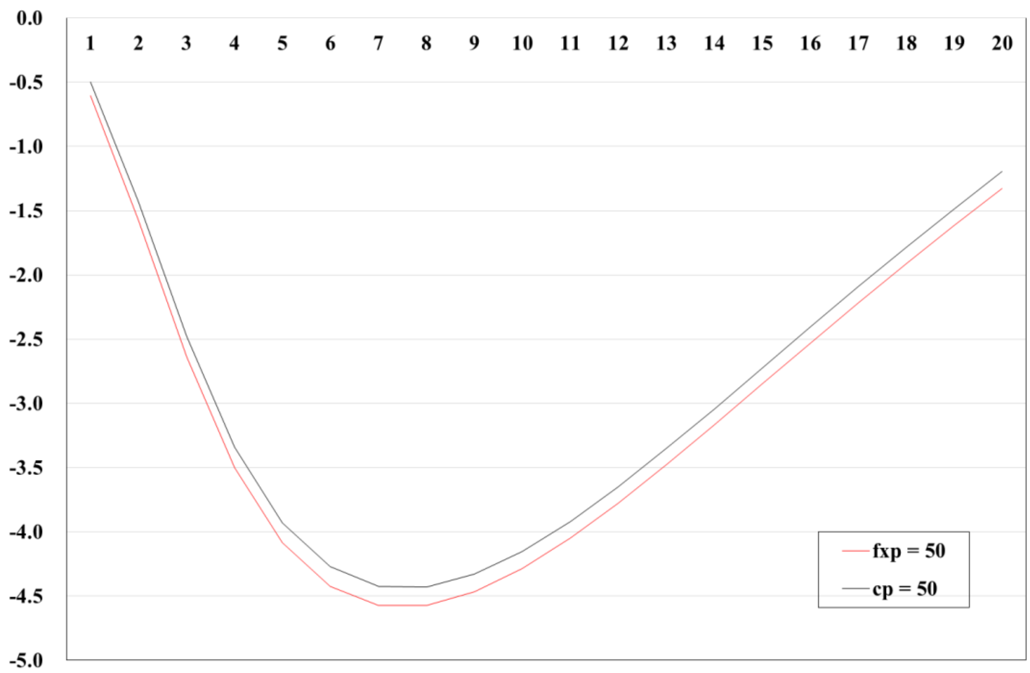


Figure 4.13: Comparison of IRFs to a Capital Quality Shock under Credit and FX Policy

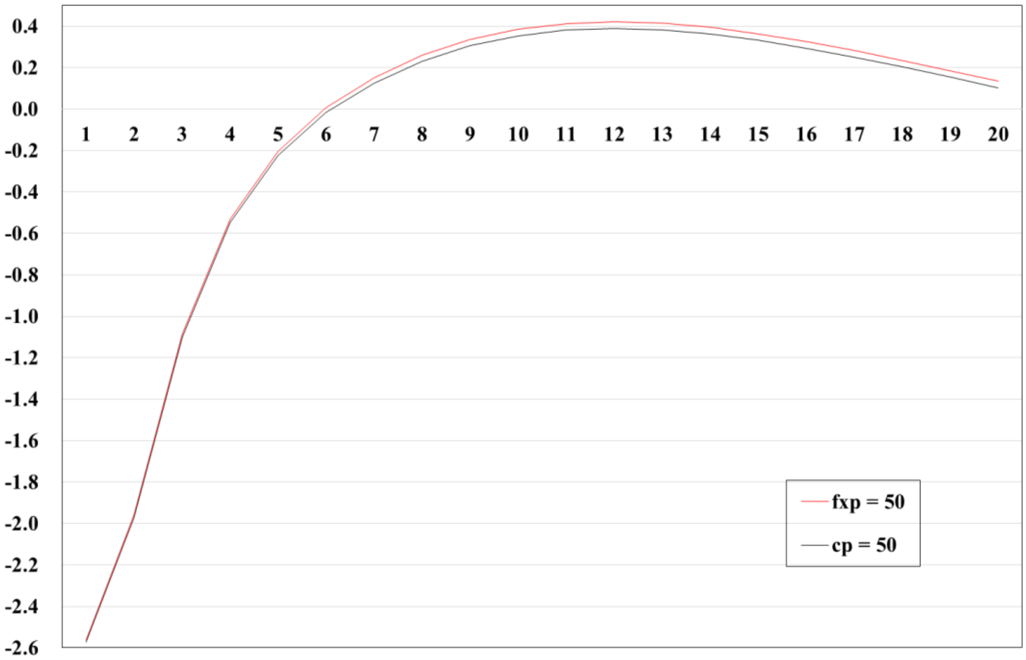
External Finance Premium (Spread)



Output



Inflation



Bank Net Worth (Bank Capital)

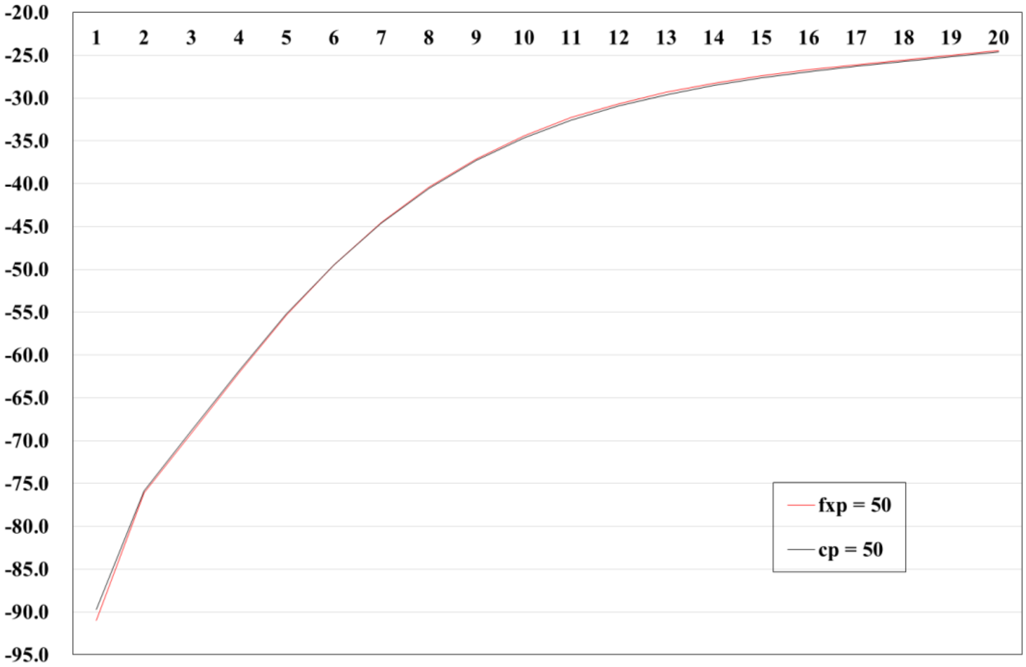
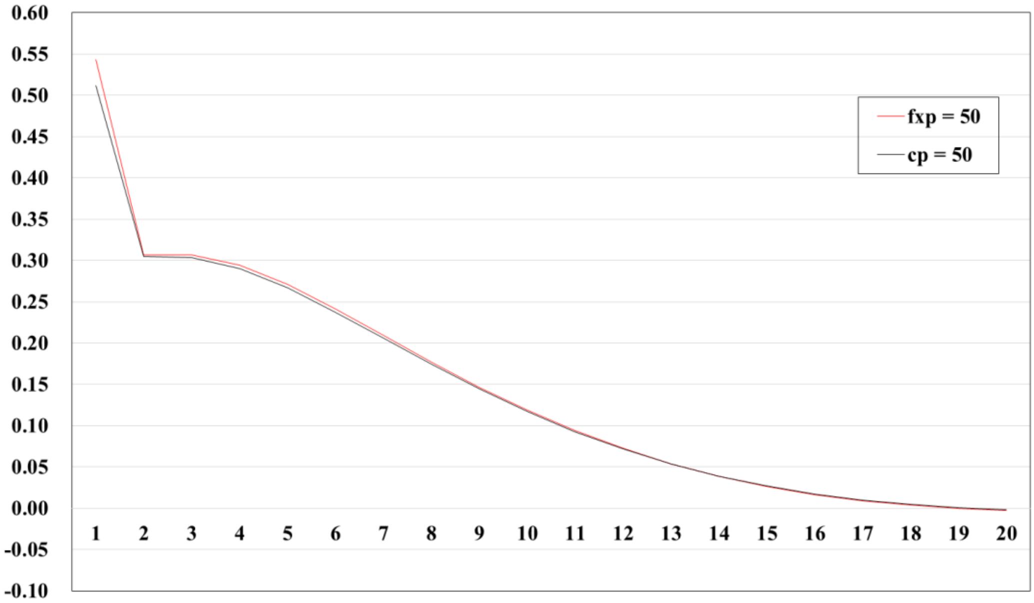
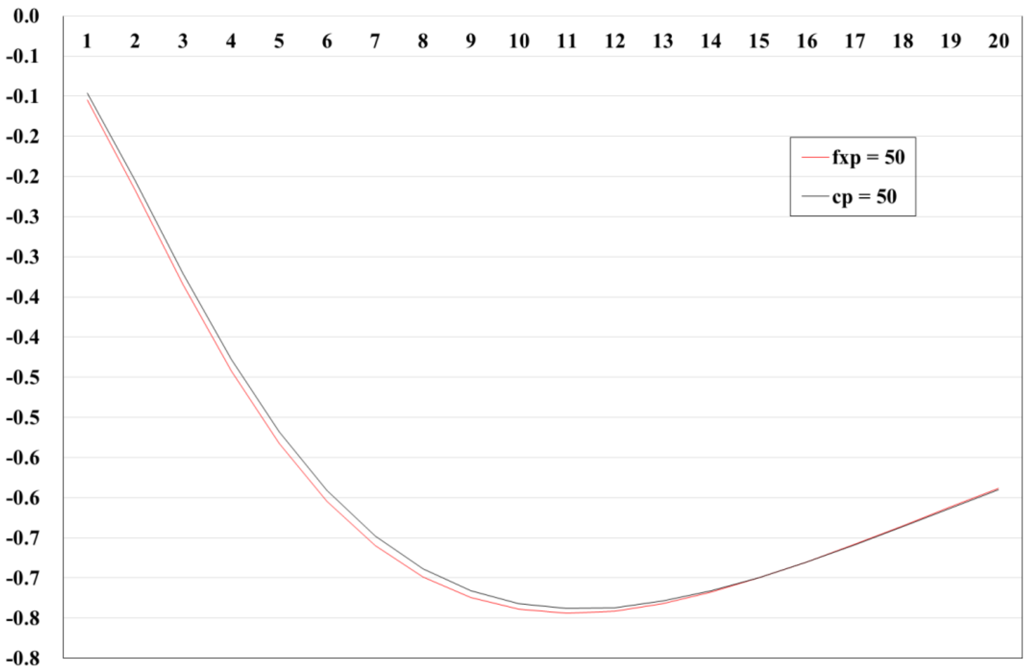


Figure 4.14: Comparison of IRFs to a Bank Net Worth Shock under Credit and FX Policy

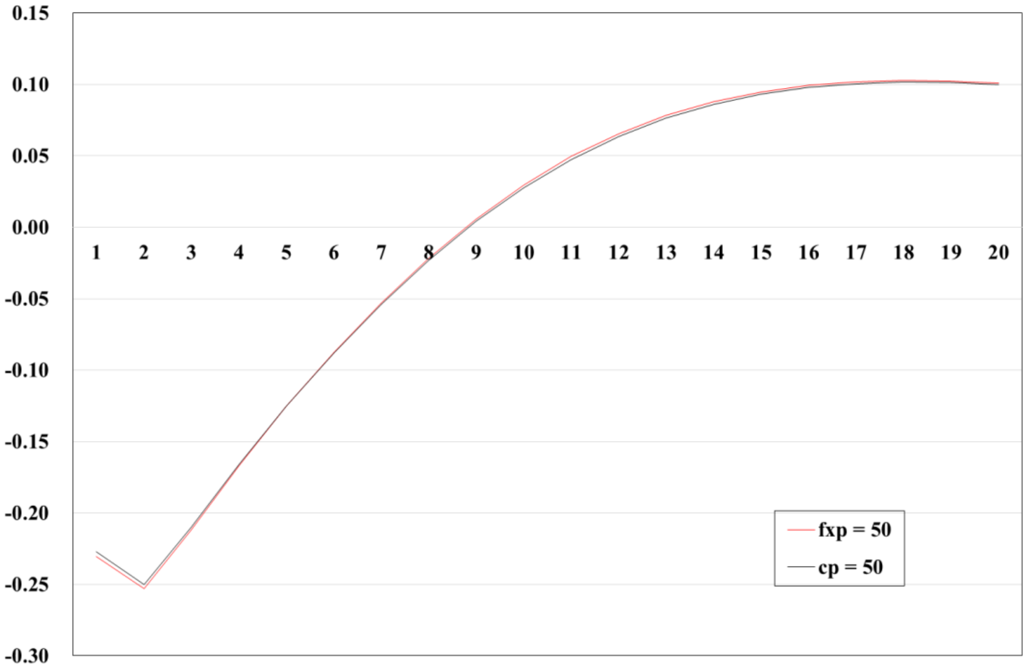
External Finance Premium (Spread)



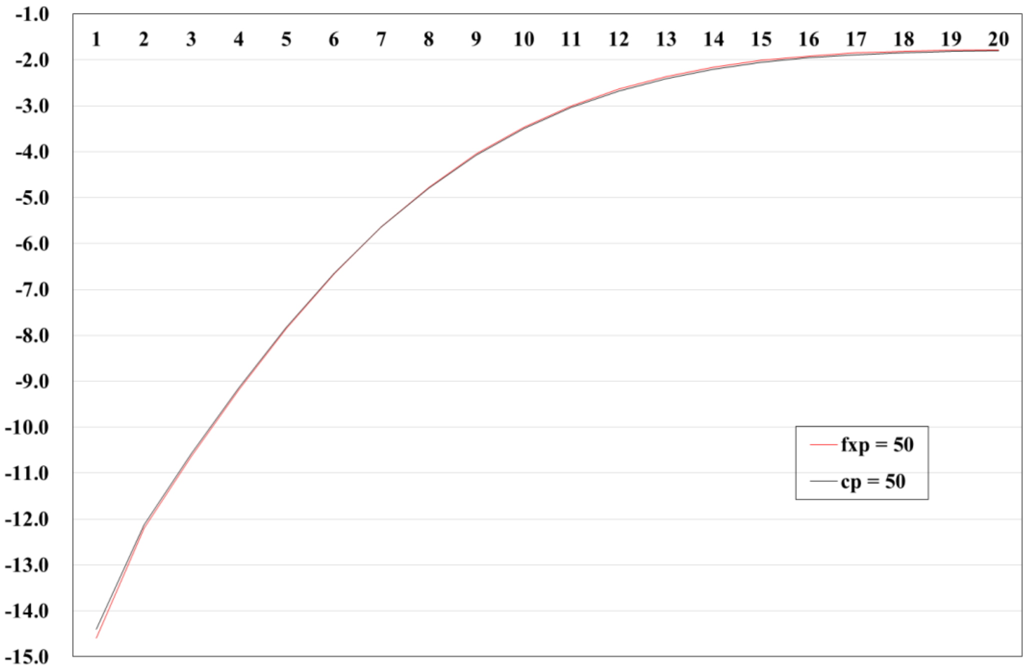
Output



Inflation



Bank Net Worth (Bank Capital)



4.3 Conclusion

For emerging market economies, the policy effectiveness of unconventional monetary policy such as the intervention in domestic credit market or the intervention in foreign exchange market beyond normal adjustment of nominal policy rate can considerably vary according to what type of shock occurs during a crisis.

First, for negative five percent shock of global interest rate originated in the external sector, it proves that the foreign exchange market intervention can be relatively more effective than the domestic credit market intervention in light of moderating fluctuations of output and inflation. Meanwhile, for negative capital quality or negative bank net worth shock mainly originated in domestic financial sector, it turns out that the intervention in domestic credit market is slightly better than the foreign exchange market intervention for the perspective of policy effectiveness. It also seems that difference in policy effectiveness occurs whether the origin of the crisis is internal or external.

Therefore, from a perspective of policy effectiveness, the Central Banks in an emerging market economy needs to conduct appropriate combinations of various unconventional monetary policy instruments considering characteristics of shocks in a crisis.

Table 4.2: The Model Summary

Economic Agents	Equation
1. Households	
Stochastic discount factor	$\Lambda_{t\,t+1} = \frac{\varrho_{t+1}}{\varrho_t}$
Euler equation	$E_t \beta \Lambda_{t\,t+1} R_{\,t+1} = 1$
Labor supply	$W_t \varrho_t = \chi L_t^{\varphi}$
Marginal utility of consumption	$\varrho_t = \frac{1}{(C_t - \mu C_{t-1})} - \beta \mu E_t \frac{1}{(C_t - \mu C_{t-1})}$
Total consumption	$C_t = {C_{Ht}}^{(1-\varsigma)} {C_{Ft}}^{\varsigma}$
Domestic goods consumption	$C_{Ht} = \varsigma \frac{P_t C_t}{P_{Ht}}$
Foreign goods consumption	$C_{Ft} = (1-\varsigma) \frac{P_t C_t}{P_{Ft}} = (1-\varsigma) \frac{P_t C_t}{S_t}$ ($\because$ $P_{Ft}^{*} = 1$, normalization)
Total price	$P_t = \frac{{P_{Ht}}^{\varsigma} {P_{Ft}}^{1-\varsigma}}{\varsigma^{\varsigma} (1-\varsigma)^{(1-\varsigma)}} = \frac{{P_{Ht}}^{\varsigma} {S_t}^{1-\varsigma}}{\varsigma^{\varsigma} (1-\varsigma)^{(1-\varsigma)}}$ ($\because$ $P_{Ft}^{*} = 1$, normalization)
2. Banks	
Marginal value of bank assets	$\nu_t = E_t\{\beta \Lambda_{t\,t+1}[(1-\theta)(R_{kt+1} - R_{t+1}) + \theta x_{t\,t+1} \nu_{t+1}]\}$
Marginal value of bank capital	$\eta_t = E_t\{(1-\theta) + \beta \Lambda_{t\,t+1} \theta z_{t\,t+1} \eta_{t+1}\}$
Total leverage	$\phi_{ct} = \frac{\phi_t}{1-\psi_t}$
Private leverage	$\phi_t = \frac{\eta_t}{\lambda - \nu_t}$
Increasing rate of bank net worth	$z_{t\,t+1} = (R_{kt+1} - R_{t+1})\, \phi_t + R_{\,t+1}$
Increasing rate of bank assets	$x_{t\,t+1} = (\frac{\phi_{t+1}}{\phi_t}) z_{t\,t+1}$
Aggregate capital	$Q_t K_{t+1} = \phi_{ct} N_t$
Net worth evolution	$N_t = N_{et} + N_{nt}$
Domestic deposit rate	$R_{D\,t+1} = \frac{e_{t+1}}{e_t} R_t^{*} \phi_t^{*} + R_t (1 - \phi_t^{*})$
3.Intermediate Good Producing Firms	
Production function	$Y_{mt} = A_t (Z_t \xi_t K_t)^{\alpha} {L_t}^{1-\alpha}$
Labor demand	$P_{mt}(1-\alpha) \frac{Y_{mt}}{L_t} = W_t$
Capacity utilization	$P_{mt} \alpha \frac{Y_{mt}}{Z_t} = \delta'(Z_t) \xi_t K_t = b Z_t^{\zeta} \xi_t K_t$
Depreciation rate	$\delta(Z_t) = \delta_c + \frac{b}{1+\zeta} Z_t^{1+\zeta}$
Return on capital	$R_{k\,t+1} = \frac{[P_{mt+1} \alpha \frac{Y_{m\,t+1}}{\xi_{t+1} K_{t+1}} + Q_{t+1} - \delta(Z_{t+1})]\, \xi_{t+1}}{Q_t}$
4. Capital-Producing Firms	
Net investment	$I_{nt} \equiv I_t - \delta(Z_t)\, \xi_t K_t$
Total investment	$I_t = {I_{Ht}}^{(1-\varsigma)} {I_{Ft}}^{\varsigma}$
Domestic investment	$I_{Ht} = \varsigma \frac{P_t I_t}{P_{Ht}}$
Foreign investment	$I_{Ft} = (1-\varsigma) \frac{P_t I_t}{P_{Ft}} = (1-\varsigma) \frac{P_t I_t}{S_t}$
Optimal net investment decision	$Q_t = 1 + \Xi_t + \frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}} {\Xi_t}' - E_t \beta \Lambda_{t,t+1} (\frac{I_{nt+1} + I_{ss}}{I_{nt} + I_{ss}})^2 {\Xi_{t+1}}'$
Investment adjustment cost	$\Xi_t = \frac{\eta_i}{2} (\frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}} - 1)^2$
Capital accumulation	$K_{t+1} = \xi_t K_t + I_{nt}$
5. Retail Firms	
Final goods production	$Y_t = D_t Y_{mt}$
Price dispersion	$D_t = \gamma D_{t-1} \Pi_{t-1}^{-\gamma_p \varepsilon} \Pi_t^{\varepsilon} + (1-\gamma) (\frac{1 - \gamma \Pi_{t-1}^{\gamma_p (1-\gamma)} \Pi_t^{\gamma - 1}}{1-\gamma})^{-\frac{\varepsilon}{1-\gamma}}$
Inflation dynamics	$\Pi_t^{1-\varepsilon} = \gamma \Pi_{t-1}^{\gamma_p (1-\varepsilon)} + (1-\gamma)(\Pi_t^{*})^{\,1-\varepsilon}$

Economic Agents	Equation
6. Small Open Economy	
Domestic and foreign price	$P_{Ht} = EX_t P^*_{Ht}$
Demand for the domestic good of foreign consumers	$C_{Ht}{}^* = C^*(P_{Ht}{}^*)^{-\nu^*}$
Uncovered interest parity condition	$E_t\{\beta \Lambda_{t,t+1}[(1-\theta)+\theta\eta_{t+1}][R_t - \frac{e_{t+1}}{e_t}R^*_t]\} = \varphi(\triangle FX_t)$
Global interest rate	$R^*_t = \Gamma^*_t \Phi_t$
Domestic factors affecting int'l rate	$\Phi_t = (-B^*_t)^{\eta^*}$
7. Monetary, Credit, and FX Policy	
Monetary policy	$i_t = i^{\rho_i}_{t-1}(\pi_t^{\kappa_\pi} y_t^{\kappa_y})^{1-\rho_i} exp(\varepsilon^i_t)$
Credit policy	$\psi_t = \psi + \upsilon E_t[(log\, R_{kt} - log\, R_t) - (log\, R_k - log\, R)]$
Foreign exchange policy	$FX_t = FX + \nu^* E_t[(log\, R_t - log\, R^*_t) - (log\, R - log\, R^*)]$
8. Other Equations	
Economy resource constraint	$Y_t = C_{Ht} + C^*_{Ht} + I_{Ht} + \Xi(\frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}})(I_{nt} + I_{ss}) + G + \tau\psi_t Q_t K_{t+1}$
Government constraint	$G + \tau\psi_t Q_t K_{t+1} = T_t + (R_{kt} - R_t)\,\psi_{t-1} Q_t K_t$
Fisher equation	$1 + i_t = R_{Dt+1}\frac{E_t P_{t+1}}{P_t}$
Resource constraint	$P^*_{Ht}C^*_{Ht} - C_{Ft} - I_{Ft} = B^*_t - R^*_{t-1}B^*_{t-1} + FX_t - R^*_{t-1}FX_{t-1}$

Chapter 5. The Effectiveness of Unconventional Monetary Policy in a Small Open Emerging Economy Ⅱ

5.1 The Model

5.1.1 Overview of Aoki, Benigno, and Kiyotaki Model (2016, ABK)

In this chapter, we consider the extension of Gertler and Karadi (2011) which is extended to a small open emerging economy. For this, the model of Aoki, Benigno, and Kiyotaki (2016) (hereafter, ABK) is used. ABK build a framework for the analysis of the transmission of external shocks to small open emerging countries. In their model, commercial banks in the domestic economy can obtain funds from both domestic depositors and foreign investors. In this model, there are five economic agents: households, banks, intermediate good firms, retail firms, and foreign investors. It is postulated the Central Bank adjusts nominal policy rate and intervenes in the foreign exchange market using foreign currency reserves.

The "Taper Tantrum" of 2013 that followed comments by the then Fed Chair Ben Bernanke about scaling back asset purchases highlighted the vulnerability of many emerging economies to external shocks, such as the monetary policy decisions of Central Banks in advanced economies. In this context, we will use the ABK model to compare the effects of two different policy tools: adjustment of the nominal policy rate and intervention in the foreign exchange market.

5.1.2 Households

The modelling of households in this chapter is similar to Gertler and Karadi (2011) and Gertler and Kiyotaki (2010). Each representative household consumes goods, purchases financial assets and provides labor. Households are composed of two types of members: a share $(1 - f)$ are workers; the remainder are bankers. A household member who is currently a banker remains a banker in the subsequent period with probability θ. This probability θ is independent of history and is the same for all households, so the relative fraction of each member in the household and in the economy does not change. A proportion $(1-\theta)f$ of existing bankers become workers in each period. On making this transition, a former banker remits all his assets to the household of which they are a member.[5]

We assume that workers can save in deposit accounts held at domestic commercial banks. They can also purchase equity, although this has an additional management cost. All financial transactions between domestic and foreign agents is assumed to take place via domestic banks. So, workers cannot hold foreign assets or borrow from foreign investors. Although domestic deposits are denominated in domestic currency, borrowing from foreign investors is denominated in foreign currency. This implies that domestic commercial banks face exchange rate risk.

[5] The household furnishes new bankers with start-up funds that is some portion of total financial assets. The size of start-up funds is small. The start-up fund's main purpose is just to give new bankers initial funds with which to begin operations and be able to raise deposits.

The utility function of a representative household is separable in consumption and labor, given by

$$max\ E_t \sum_{t=0}^{\infty} \beta^t\ [ln\ (C_t - \frac{\chi}{1+\varphi} L_t^{1+\varphi})] \tag{5.1}$$

where $0 < \beta < 1$, χ, $\varphi > 0$. C_t is household consumption and L_t denotes the number of hours worked.

The households' budget constraint is

$$C_t + Q_t K_t^h + f(K_t^h)^6 + D_t = w_t L_t + [Z_t + (1-\delta)Q_t]K_{t-1}^h + R_t D_{t-1} + \Gamma_t \tag{5.2}$$

where K_t^h is the stock of equity the household holds. Q_t represents the real price of equity, $f(K_t^h)$ denotes the cost of purchasing equity and D_t is the household's deposit at commercial banks. w_t represents the real wage, R_t is the real interest rate paid on bank deposits and Γ_t denotes real profits received by the household. $[Z_t + (1-\delta)Q_t]K_{t-1}^h$ represents the earning the household can acquire when they provide their funds to business directly without the intermediation by banks.

The household choose consumption, labour supply, bank deposits and the amount of equity to purchase. Their first order conditions are

$$w_t = \chi L_t^{\varphi} \tag{5.3}$$

$$1 = E_t\ [\Lambda_{t\ t+1} \frac{Z_{t+1} + (1-\delta)Q_{t+1}}{Q_t + f'(K_t^h)}] \tag{5.4}$$

$$1 = E_t\ (\Lambda_{t\ t+1} R_{t+1}) \tag{5.5}$$

$$Q_t = 1 + \Sigma\left(\frac{I_t}{I}\right) + \left(\frac{I_t}{I}\right)\Sigma'\left(\frac{I_t}{I}\right) \tag{5.6}$$

Q_t is price of equity in terms of goods.

5.1.3 Banks

Commercial banks operate in a competitive market. They acquire deposits from both domestic households and foreign investors. They issue loans to nonfinancial firms at the stochastic loan rate. Furthermore, the bank objective is to maximize bank's terminal net worth, denoted as

$Bank's\ objective$:

$$V_t = E_t \sum_{j=1}^{\infty} \Lambda_{t,t+j}\, \theta^{j-1}(1-\theta) n_{t+j}] \tag{5.7}$$

where n_{t+j} represents the net worth of bank, $\Lambda_{t,t+j}$ represents the stochastic discount factor, and θ represents the survival rate of the bank.

---

[6] Households purchase equity. These purchases are subject to a management cost, given by $f(K_t^h) = \frac{\zeta}{2}(K_t^h)^2$.

Equation (5.7) can be also represented as

$$V_t = E_t \Lambda_{t,t+1}[(1-\theta)n_{t+1} + \theta V_{t+1}] \tag{5.8}$$

Meanwhile, the flow of funds constraint of a representative bank can be shown as

$Motion\ of\ aggregate\ bank\ net\ worth$:

$$n_t = [Z_t + (1-\delta)Q_t]K_{t-1}^b - R_t D_{t-1} - \epsilon_t R_{t-1}^* D_{t-1}^* \tag{5.9}$$

where K_{t-1}^b denotes bank's capital holding, D_t and D_t^* are domestic real deposit and foreign debt, respectively, R_t^* is the gross global interest rate, ϵ_t denotes the real exchange rate.

Meanwhile, the bank's balance sheet can be represented as

$$Q_t K_t^b = \phi_t n_t = n_t + D_t + \epsilon_t D_t^* \tag{5.10}$$

Total capital is the sum of capital owned by banks (K_t^b) and capital owned by households (K_t^h).

$$K_t = K_t^b + K_t^h \tag{5.11}$$

In addition, capital evolves according to the equation of capital accumulation.

$$K_t = (1-\delta)K_{t-1} + I_t \tag{5.12}$$

where the investment cost function has the form of $[1 + \frac{\kappa_I}{2}(\frac{I_t}{I} - 1)^2]I_t$.

(Agency Problem of Banks)

It is supposed that there exists an asymmetric information problem between banks and firms. Banks are able to divert a portion $\lambda(x_t)$ of total financial assets. Banks also transfer diverted assets to the household of which he or she is a member.

$Incentive\ constraint\ for\ lenders\ to\ furnish\ funds\ to\ a\ bank$:

$$V_t \geq \lambda(x_t)^{7} Q_t K_t^b \tag{5.13}$$

where x_t[8] represents the fraction of assets borrowed from foreign investors.

In equation (5.13), the left-hand side represents what a bank would lose through diverting a portion of financial assets. On the other hand, the right-hand side shows the benefits from a diversion. In other words, equation (5.13) reflects the fact that the bank is subject to a limited commitment problem. The bank can only lend to firms when the payoff from lending (V_t) is larger than the utility from diverting funds ($\lambda(x_t)Q_t K_t^b$).

Then, a representative bank decides the components of its' balance sheet such as $K_t^b,\ D_t,\ D_t^*$ by maximizing its expected discounted value, given by.

$$V_t = E_t \Lambda_{t,t+1}[(1-\theta)n_{t+1} + \theta V_{t+1}] \tag{5.14}$$

Dividing equation (5.14) by n_t, ψ_t which can be interpreted as Tobin's Q[9] is derived as:

$$\psi_t = \frac{V_t}{n_t} = E_t[\Lambda_{t,t+1}(1-\theta+\theta\psi_{t+1})\frac{n_{t+1}}{n_t}] \tag{5.15}$$

On the other hand, using the balance sheet constraint of (5.9), following condition is derived.

$$\frac{n_{t+1}}{n_t} = \left[\frac{Z_{t+1} + (1-\delta)Q_{t+1}}{Q_t}\right][\frac{Q_t K_t^b}{n_t}] - R_{t+1}\frac{D_t}{n_t} - R_{t+1}^* \frac{\epsilon_{t+1}}{\epsilon_t}\frac{\epsilon_t D_t^*}{n_t} \tag{5.16}$$

$$= \left[\frac{Z_{t+1} + (1-\delta)Q_{t+1}}{Q_t} - R_{t+1}\right]\phi_t + \left[R_{t+1} - R_{t+1}^*\frac{\epsilon_{t+1}}{\epsilon_t}\right]\phi_t x_t + R_{t+1} \tag{5.17}$$

---

[7] $\lambda(x_t) = \kappa_\lambda(1 + \frac{\varsigma}{2}x_t^2)$ $(\kappa_\lambda,\ \varsigma > 0)$, κ_λ represents the degree of moral hazard of bank and ς reflects the degree of domestic bias in the finance of bank.

[8] $\frac{\epsilon_t D_t^*}{Q_t K_t^b}$

[9] $\frac{Market\ value\ of\ firm\ capital}{Replacement\ cost\ of\ capital}$

Then, applying the balance sheet constraint and leverage multiple[10] into (5.15), the equation relating to ψ_t is finally derived. Now, the bank decides the leverage multiple and fraction of foreign debt, $(\phi_t,\ x_t)$, in order to maximize Tobin's Q ratio (ψ_t).

$$max \quad \psi_t \ = \ u_t\phi_t + u_{d^*t}\phi_t x_t + \nu_t \tag{5.18}$$

subject to the incentive constraint

$$\psi_t \ \geq \ \lambda(x_t)\phi_t \ = \ \frac{\kappa_\lambda}{2}(1+\frac{\varsigma}{2}x_t^2)\phi_t \tag{5.19}$$

where

$$\begin{aligned} u_t \ &= \ E_t[\ \Lambda_{t\,t+1}(1-\theta+\theta\psi_{t+1})\left(\frac{Z_{t+1}+(1-\delta)Q_{t+1}}{Q_t} - R_{t+1}\right)] \\ &= \ E_t[\Omega_{t\,t+1}(\frac{Z_{t+1}+(1-\delta)Q_{t+1}}{Q_t} - R_{t+1})] \ > 0 \end{aligned} \tag{5.20}$$

$$\begin{aligned} u_{d^*t} \ &= \ E_t[\Lambda_{t\,t+1}(1-\theta+\theta\psi_{t+1})\left(R_{t+1} - \frac{\epsilon_{t+1}}{\epsilon_t}R^*_{t+1}\right)] \\ &= \ E_t[\Omega_{t\,t+1}(R_{t+1} - \frac{\epsilon_{t+1}}{\epsilon_t}R^*_{t+1})] \ > 0 \end{aligned} \tag{5.21}$$

$$\nu_t \ = \ E_t[\Omega_{t\,t+1}R_{t+1}] \tag{5.22}$$

u_t is the excess return on capital over domestic deposit, u_{d^*t} is the cost advantage of debt denominated in foreign currency over domestic deposit, $\Omega_{t\,t+1}$ represents the stochastic discount factor.

<u>Figure 5.1: The Commerical Bank Balance Sheet</u>

Assets	Liabilities
Loan Portfolio $(Q_tK_t^b)$	Deposits from Domestic Households (D_t)
	Foreign Debt from Foreign Investors $(\epsilon_t D_t^*)$
	Capital or Net Worth (n_t)

10 $\frac{Q_tK_t^b}{n_t}$

5.1.4 Intermediate Good Firms

Intermediate goods firms produce intermediate goods and sell these to retail firms in a perfect competition environment. Firms producing intermediate products get capital in the end of each period *t* to manufacture final product next period.

Intermediate goods producing firms produce Y_{mt} utilizing capital, imported good, and labor as inputs. The production functions for intermediate goods is

$$Y_{mt} = A_t \left(\frac{\xi_t K_{t-1}}{\alpha_K}\right)^{\alpha_K} \left(\frac{M_t}{\alpha_M}\right)^{\alpha_M} \left(\frac{L_t}{1-\alpha_K-\alpha_M}\right)^{1-\alpha_K-\alpha_M} \tag{5.23}$$

Where Y_{mt} is output, A_t is total factor productivity, K_t is capital, M_t represents imported material inputs, L_t is labour and α_K and α_M are the shares of capital and imported materials, respectively. ξ_t represents a capital quality shock that provides an exogenous change in the capital value. Hence, $\xi_t K_t$ is the effective capital. It is assumed that ξ_t follows an AR(1) process.

Through cost minimization,

$$\frac{\epsilon_t M_t}{Z_t \xi_t K_{t-1}} = \frac{\alpha_M}{\alpha_K} \tag{5.24}$$

$$\frac{w_t L_t}{Z_t \xi_t K_{t-1}} = \frac{1-\alpha_K-\alpha_M}{\alpha_K} \tag{5.25}$$

This implies that marginal cost is

$$MC_t = \frac{1}{A_t}(z_t)^{\alpha_K}(\epsilon_t)^{\alpha_M}(w_t)^{1-\alpha_K-\alpha_M} \tag{5.26}$$

Since intermediate firms operate in a competitive market, they set price equal to marginal cost, $P = P_t^I = MC_t$, where marginal cost is given by (5.26).

5.1.5 Retail Firms

Retail firms purchase intermediate goods from firms which produce intermediate goods. There exists a continuum of firms producing final products who transform identical intermediate goods into differentiated retail goods without cost. Then, they sell these in a monopolistically competitive final goods market.

Final output has a form of a composite of retail goods produced by each individual retail firm.

$$Y_t = [\int_0^1 Y_{ft}^{\frac{\eta-1}{\eta}} df]^{\frac{\eta}{\eta-1}} \tag{5.27}$$

where Y_{ft} is output by retailer f and Y_t is the final output. η denotes the substitution elasticity between individual final goods (η > 1).

The demand for individual final goods can be shown to be,

$$Y_{ft} = \left(\frac{P_{ft}}{P_t}\right)^{-\eta} Y_t \tag{5.28}$$

with

$$P_t = [\int_0^1 P_{ft}^{1-\eta} df]^{\frac{1}{1-\eta}} \tag{5.29}$$

The problem of retail firms[11] is

$$\max_{p_{it},\ y_{it}} \ E_0\{\sum_{t=0}^{\infty} \Lambda_{0,t}[(\frac{P_{ft}}{P_t} - MC_t)Y_{ft} - \frac{\kappa}{2}(\frac{P_{ft}}{P_{ft-1}} - 1)^2 Y_t]\} \tag{5.30}$$

where $\Lambda_{0,t}$ represents the stochastic discount factor.

The solution to this problem implies the New Keynesian Phillips curve.

$$\widehat{\pi_t} = \frac{\eta-1}{\kappa}\widehat{MC}_t + \beta E_t(\widehat{\pi_{t+1}}) \tag{5.31}$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ and $\widehat{y_t} = \frac{y_t - y}{y}$ represents output gap, proportional deviation of output from steady state, respectively.

[11] Retail firms face a cost of adjusting price, given by $\frac{\kappa}{2}(\frac{P_{ft}}{P_{ft-1}} - 1)^2$.

5.1.6 Monetary and Foreign Reserve Policies

(Monetary Policy)

The Central Bank's objective is set to stabilize inflation. To do this, it sets the risk free nominal rate (i_t) on household deposits following a traditional Taylor rule.

$$i_t - i = (1 - \rho_i)\varpi_\pi(\pi_t - 1) + \rho_i(i_{t-1} - i) + \varepsilon_t^i \qquad (5.32)$$

where i_t is the risk-free nominal rate, ρ_i is an interest rate smoothing component, ϖ_π is the inflation coefficient and ε_t^i denotes a monetary policy shock which follows an AR(1) process.

The Central Banks also conduct two kinds of unconventional monetary policy. It intervenes in the domestic credit market by providing direct loan to domestic non-financial firms. It also intervenes in the foreign exchange market.

(Foreign Reserve Policy)

We assume the foreign exchange market intervention is given following a FX intervention rule.

$$FX_t - FX = (1 - \rho_{FX})\varpi_{FX}(\epsilon_t - \epsilon) + \rho_{FX}(FX_{t-1} - FX) + \varepsilon_t^{FX} \qquad (5.33)$$

where FX_t is the foreign reserve of the Central Bank, ρ_{FX} is a smoothing component of foreign reserve rule, ϖ_{FX} is the coefficient of foreign reserve. ε_t^{FX} denotes the foreign reserve shock following an AR(1) process.

Figure 5.2: The Central Bank Balance Sheet

Assets	Liabilities
Foreign Reserve (FX_t)	Debt (D_{gt})

5.1.7 Resource Constraint

Domestic output (Y_t) is utilized for domestic consumption, domestic investment and adjustment cost of investment, and export. In addition, there is also domestic output which is used for paying the cost of changing prices and managing the capital owned by households. This implies the economy wide resource constraint

$$Y_t \ = \ C_t + [1 + \frac{\varpi_I}{2}(\frac{I_t}{I})^2]\, I_t \ \ + EX_t + \ \frac{\kappa}{2}(\pi_t - 1)^2 Y_t \ - \ f\big(K_t^h\big) \tag{5.34}$$

where $\frac{\kappa}{2}(\pi_t - 1)^2 Y_t$ is the cost of changing prices and $f\big(K_t^h\big)$ is the cost of managing capital owned by households.

GDP[12] and net output are given by

$$Y_t^{GDP} \ = \ Y_t - \ \epsilon_t M_t \tag{5.35}$$

$$Y_t^n \ = \ Y_t - \ \epsilon_t M_t \ - \ \frac{\kappa}{2}(\pi_t - 1)^2 Y_t \ - \ f\big(K_t^h\big) \tag{5.36}$$

where Y_t^{GDP} represents GDP and Y_t^n denotes net output.

The evolution of net foreign debt is given by

$$D_t^* = \ R_{t-1}^* D_{t-1}^* + \ M_t - \frac{1}{\epsilon_t} EX_t \tag{5.37}$$

In addition, total deposits denominated in foreign currency, comprising foreign currency deposits held at commercial banks and foreign reserve held by the Central Bank, are

$$D_t^* = \ D_t^{*f} + \ FX_t \tag{5.38}$$

where D_t^{*f} represents the deposit denominated in foreign currency from foreign countries.

Exports depend on foreign demand and the real exchange rate; they are given by

$$EX_t = (\frac{P_t}{e_t P_t^*})^{-\varphi}\, Y_t^* = {\epsilon_t}^{\varphi} Y_t^* \tag{5.39}$$

where e_t represents the nominal exchange rate, $\epsilon_t (= \frac{e_t P_t^*}{P_t})$ denotes the real exchange rate, P_t^* represents the price level of foreign country, φ represents a constant price elasticity of foreign demand, Y_t^* denotes exogenous foreign demand. It is also postulated that $P_t^* = \ P^* = 1$.

[12] GDP is equivalent to output minus import.

5.2 Empirical Results

5.2.1 Calibration

The 15 parameters of the model are calibrated to reflect the distinct macroeconomic characteristics of Korea, similar to the calibration strategy used in chapters 3 and 4. Where, possible, we calibrate using Korean time-series data; some parameters are also calibrated following Aoki, Benigno, and Kiyotaki (2016).

Some parameters, relating to the open economy aspects of the model have not been calibrated in previous chapters; these comprise the ratio of foreign debt to commercial bank's total assets, the foreign debt/GDP ratio and the capital/GDP ratio. These are calibrated using the national statistics of Korea as of 2016.

Other parameters, such as the cost parameter in household's direct finance, the inverse elasticity of net investment to capital and the price elasticity of export demand, are calibrated using values in Aoki, Benigno, and Kiyotaki (2016).

Other parameters, for example the coefficients of the interest rate and foreign intervention rules are calibrated using standard values in the literature. In the interest rate rule, the coefficient on inflation is set as 1.5 while the smoothing parameter is set as 0.782, reflecting the structure of the Korean economy. In a similar way, in the foreign exchange intervention policy rule, coefficient on the real exchange rate is set as 1.5 and smoothing parameter is set as 0.782.

Table 5.1: Calibrated Parameters

Parameters	Description	Value	Parameters	Description	Value
< Baseline Parameters >					
β	Discount factor	0.988	ς	Cost parameter in household's direct finance	9.85 x 10^{-4}
ζ	Domestic bias in funding	6.4	η_i	Inverse elasticity of net investment to capital value	1.728
χ	Relative utility weight of labor	12.00	η	Substitution elasticity in goods	4.167
φ	Inverse Frisch elasticity in labor supply	0.2	γ	Probability of keeping prices fixed	0.525
λ	Diverting fraction of capital	0.374	κ_I	Cost of adjusting investment goods	1
ω	Transfer to entering bankers	0.002	φ	Price elasticity of export demand	2
θ	Survival rate of bankers	0.94	δ	Depreciation rate in steady state	0.02
α_K	Share of capital	0.3	ρ_i	Smoothing parameter in interest rate rule	0.782
α_M	Share of imported good	0.15	ρ_{FX}	Smoothing parameter in foreign exchange rule	0.782

< Baseline Steady State Values >					
R^*	Global interest rate	1.02	$\frac{K}{Y-\epsilon M}$	Capital/GDP ratio	16.5
R	Domestic deposit interest rate	1.06	$\frac{K^b}{K}$	Share for capital financed by bank	0.66
R_K	Return rate of capital of bank	1.08	$\frac{\epsilon D^*}{Y-\epsilon M}$	Foreign debt/GDP ratio	0.27
ϕ	Leverage multiple	6	$Y-\epsilon M$	GDP	16.4
x	Foreign debt/bank's total asset	0.03	$f(K^h)$	Cost of direct finance	0.049

5.2.2 Simulation Results

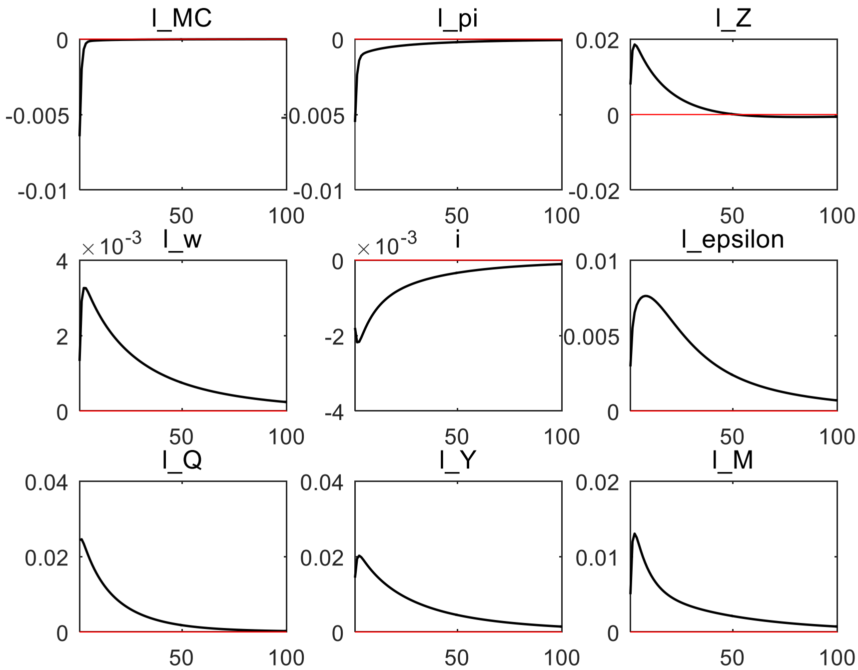
We analyse three types of shocks are conducted. We consider the effect of a 1% rise in total factor productivity shock, a 5% reduction in capital quality shock and a 50bp rise in the global interest rate.

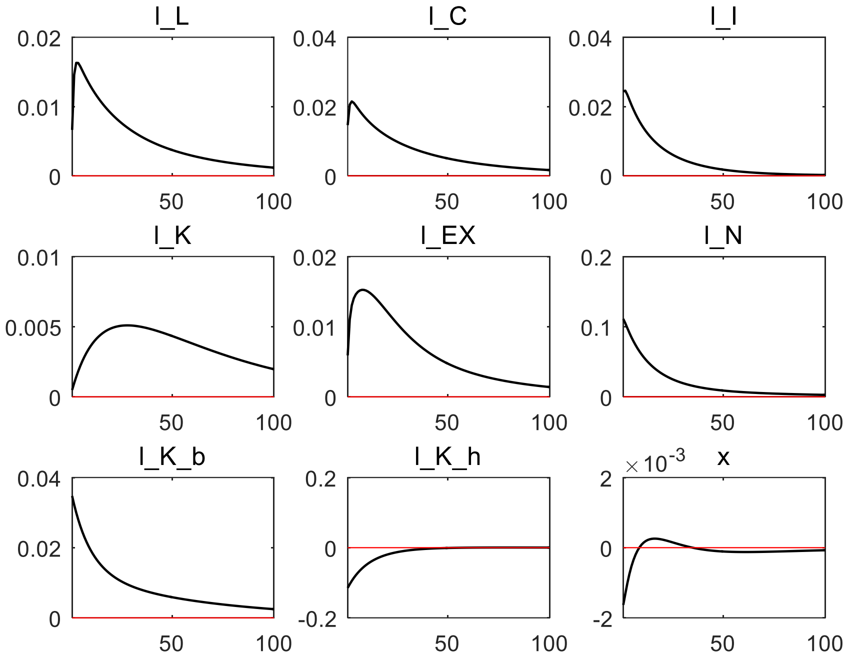
① A 1% Increase in Total Factor Productivity

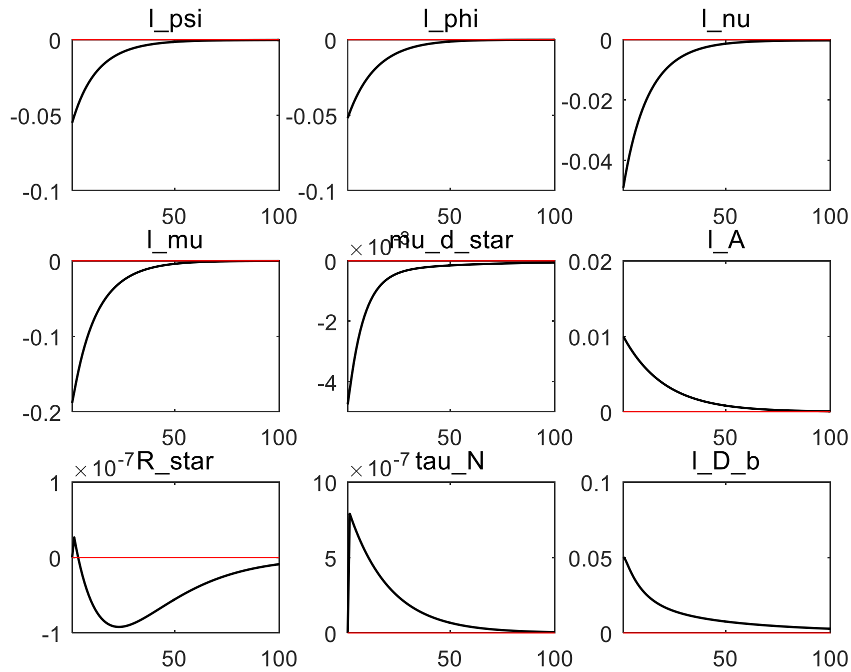
We model the total factor productivity shock as an AR(1) process having an autoregressive coefficient of 0.95. It is also supposed the Central Bank does not conduct any interest rate or foreign reserve policy in the simulation.

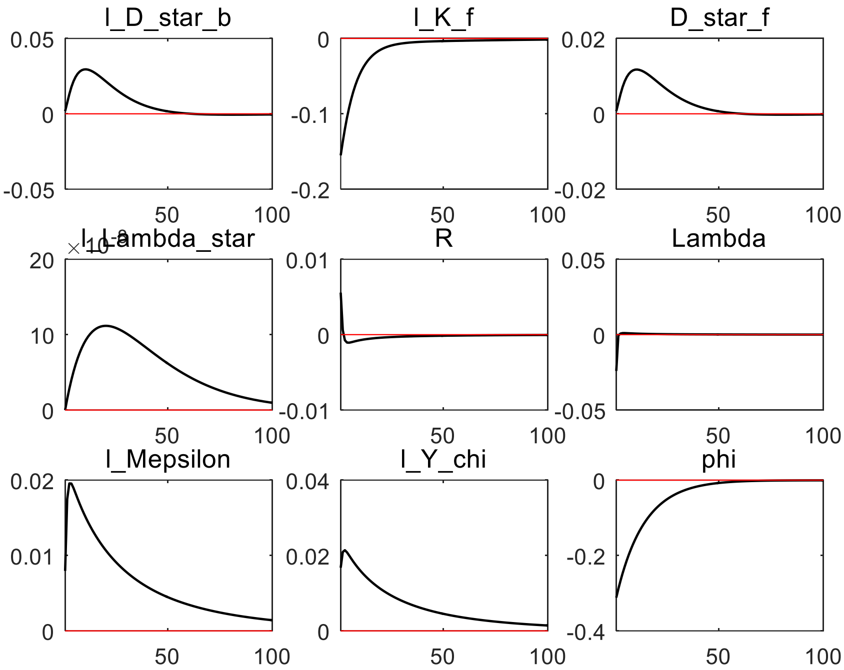
The positive shock to TFP, increases net output, consumption, and exports. Net output and consumption are boosted by more than 2%. Exports increase by more than 1.5%. The real exchange rate depreciates, by less than 1%. Inflation decreases by 0.5% and the nominal interest rate decreases by 0.2%. In addition, investment and the price of capital increase by more than 2% and bank net worth rises by more than 10%. There is substantial persistence, reflected in a slow convergence of many of our variables back to their steady state values.

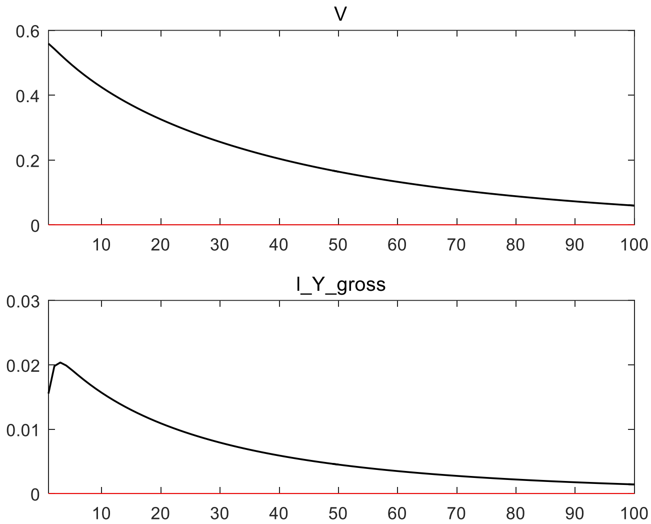
Figure 5.3: IRFs to a Total Factor Productivity Shock




l_L
l_C
l_I
l_K
l_EX
l_N
l_K_b
l_K_h
x


l_psi
l_phi
l_nu
l_mu
mu_d_star
l_A
R_star
tau_N
l_D_b


l_D_star_b
l_K_f
D_star_f
l_Lambda_star
R
Lambda
l_Mepsilon
l_Y_chi
phi

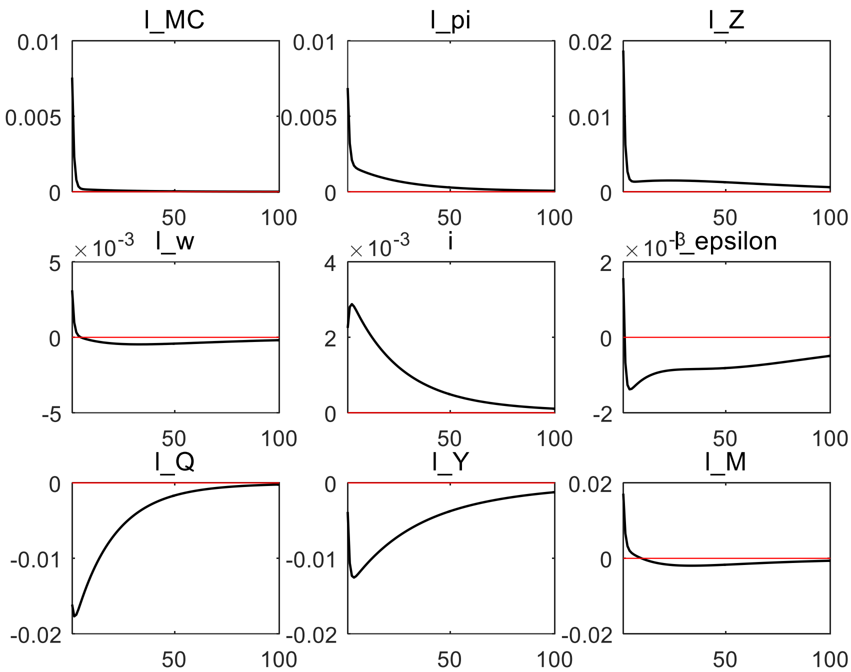

V
l_Y_gross

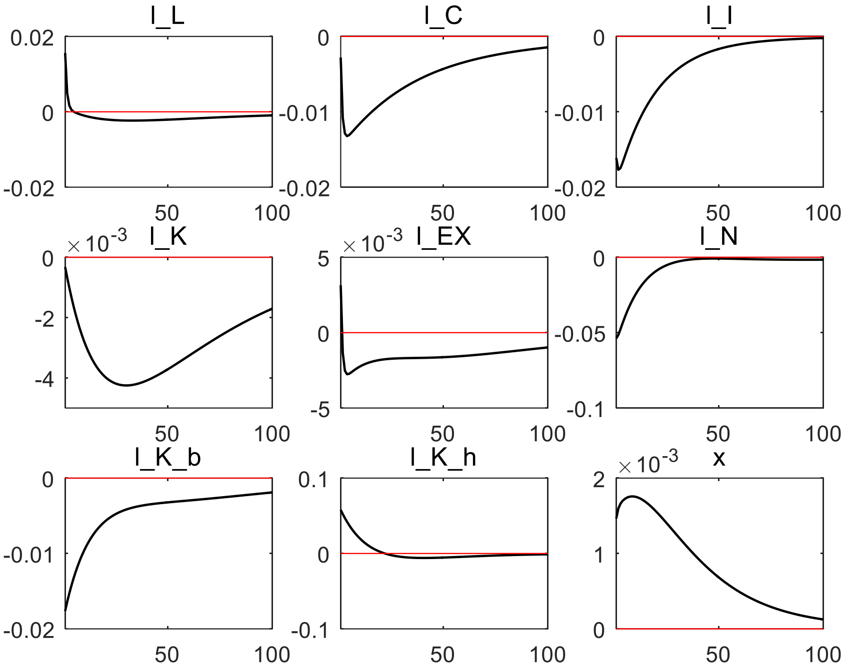
② **A 5% decrease in Capital Quality**

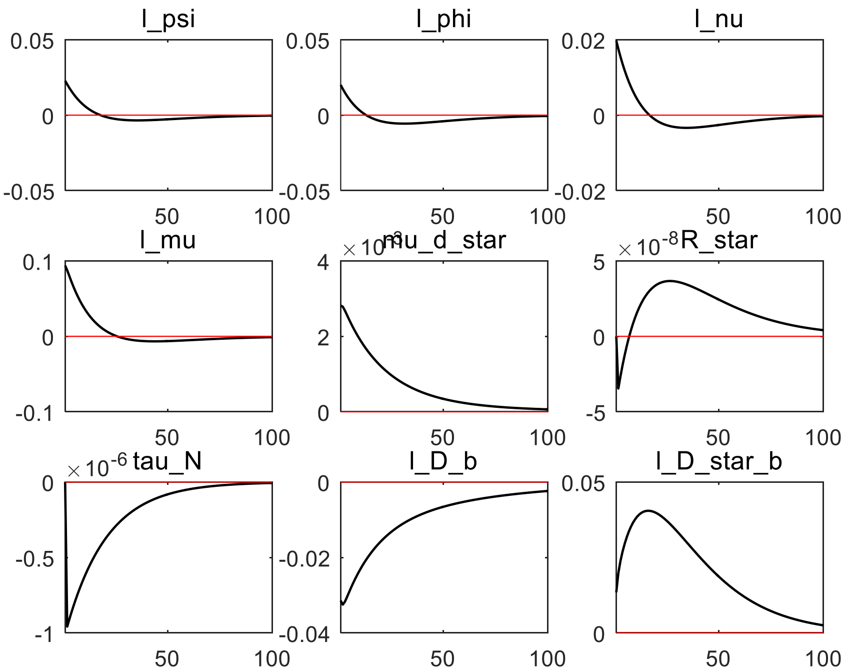
Here we simulate the impact of a 5% reduction in the quality of financial assets held by banks. We model the capital quality shock as an AR(1) with persistence of 0.95. We again assume that the Central Bank does not conduct any interest rate or foreign reserve policy.

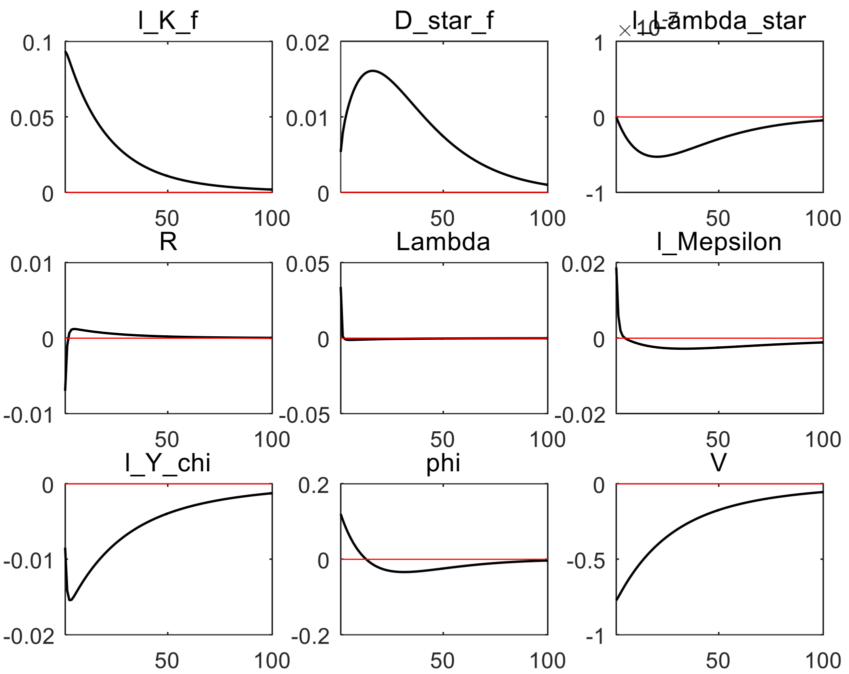
The negative shock to capital quality lowers the quantity of effective capital and bank capital by 5%. In response, the price of capital drops by more than 1.5%. The real exchange rate appreciates, leading to a fall in exports of 0.25% and an increase in imports of about 2%. The inflation increases, leading to an increase in the interest rate. Consumption declines by more than 1% and investment falls by more than 1.5%. Output falls by more than 1%.

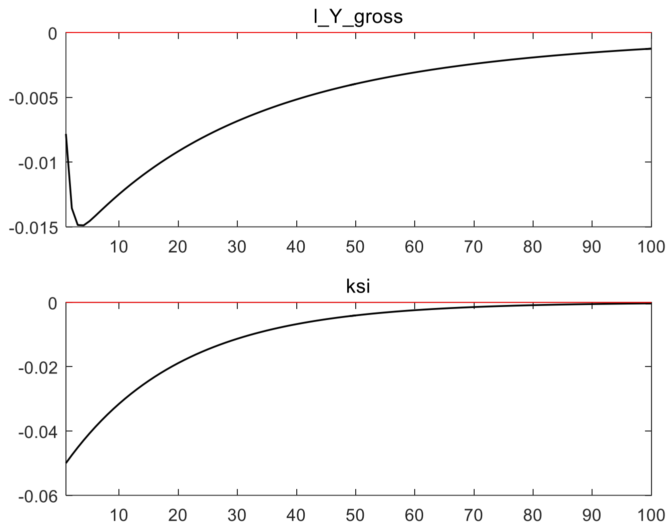
Figure 5.4: IRFs to a Capital Quality Shock




l_L
l_C
l_I
l_K
l_EX
l_N
l_K_b
l_K_h
x


l_psi
l_phi
l_nu
l_mu
mu_d_star
R_star
tau_N
l_D_b
l_D_star_b


l_K_f
D_star_f
l_Lambda_star
R
Lambda
l_Mepsilon
l_Y_chi
phi
V

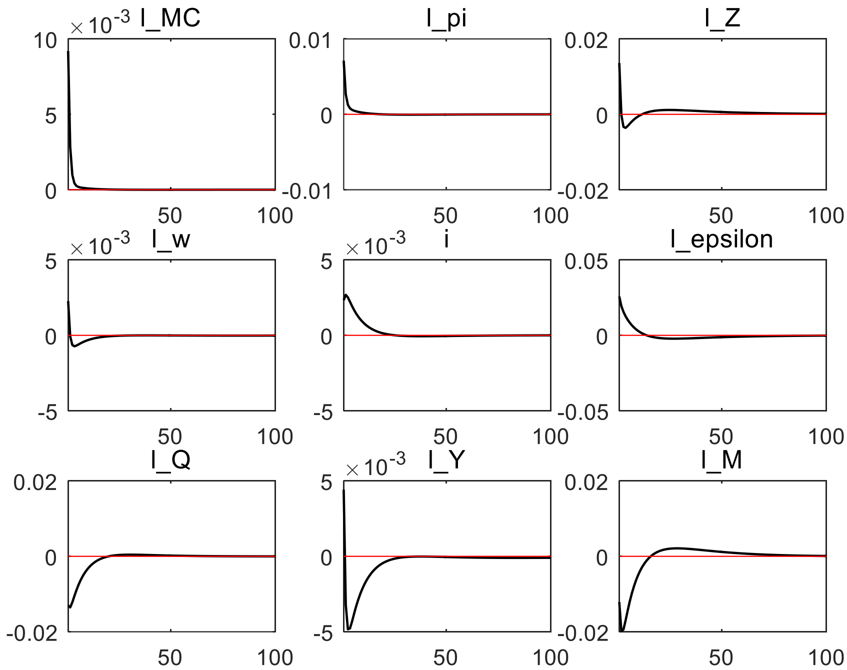

l_Y_gross
ksi

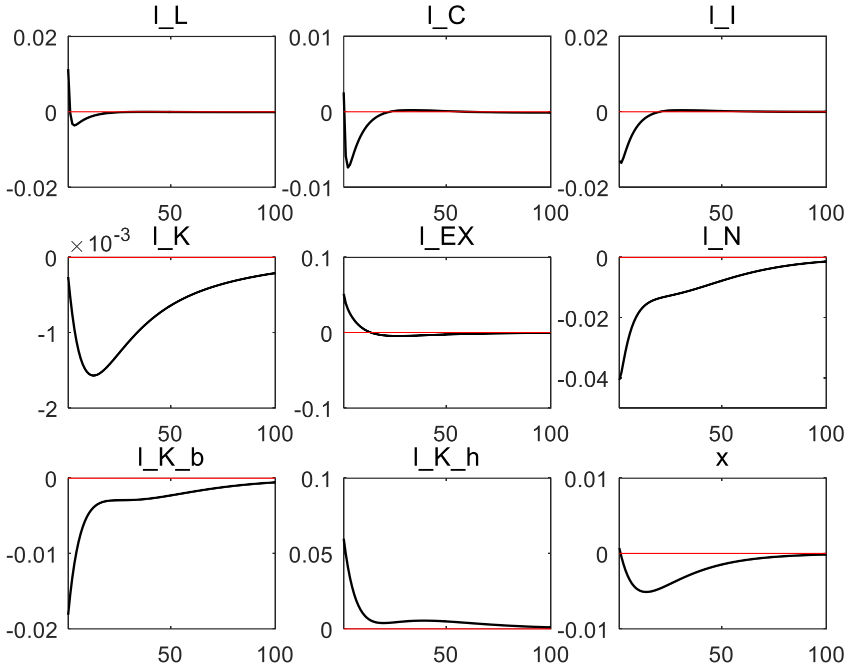
③ A 50bp Rise in the Global Interest Rate

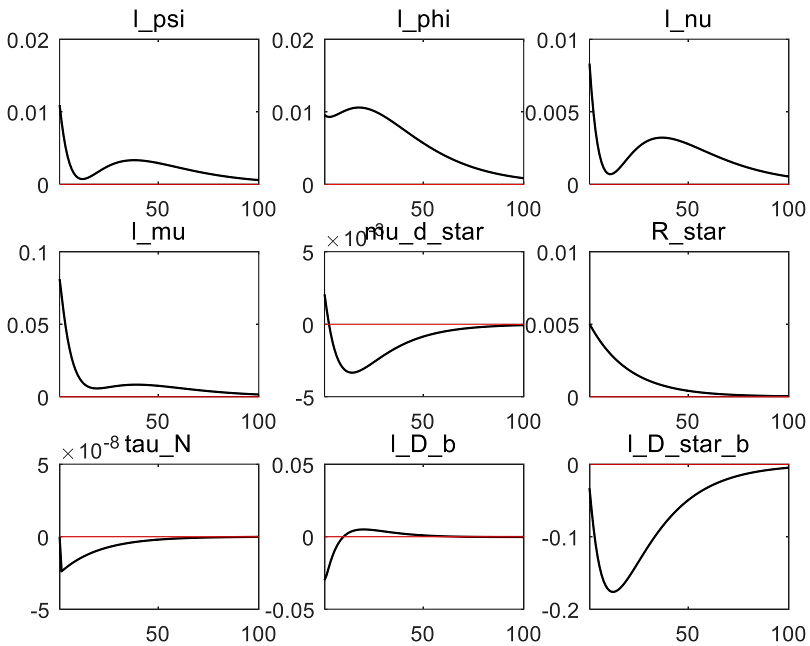
We next analyze the impact of a 50bp increase in the global interest rate. This shock is modelled as an AR(1) process having autoregressive coefficient of 0.95. As before, we assume that there is no interest rate or foreign reserve policy conducted by the Central Bank.

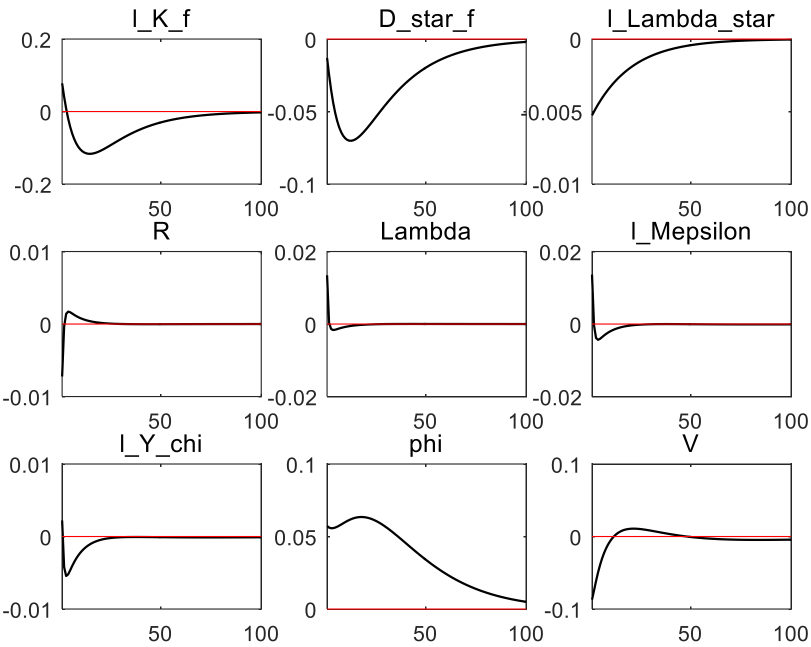
Following the shock, the real exchange rate depreciates by about 2.5%. As a result, exports increase by about 5% and imports drop by about 2%. Inflation increases by about 1%, leading to a rise in the nominal rate of 25bp. The capital price falls by more than 1%. With the combination of the decreased capital price and the depreciated real exchange rate, bank net worth also decreases, by about 4%. Net output and consumption both decrease by about 0.5%.

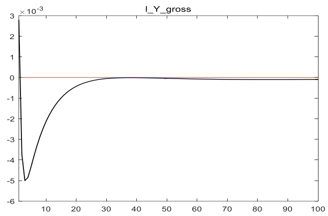
Figure 5.5: IRFs to a Global Interest Rate Shock




l_L
l_C
l_I
l_K
l_EX
l_N
l_K_b
l_K_h
x


l_psi
l_phi
l_nu
l_mu
mu_d_star
R_star
tau_N
l_D_b
l_D_star_b


l_K_f
D_star_f
l_Lambda_star
R
Lambda
l_Mepsilon
l_Y_chi
phi
V
0.2
0
-0.2
-0.05
-0.1
-0.005
-0.01
0.01
0.02
-0.02
0.1
0.05
-0.1
50
100


l_Y_gross
×10⁻³
10
20
30
40
50
60
70
80
90
100

(Foreign Reserve Policy Simulation)

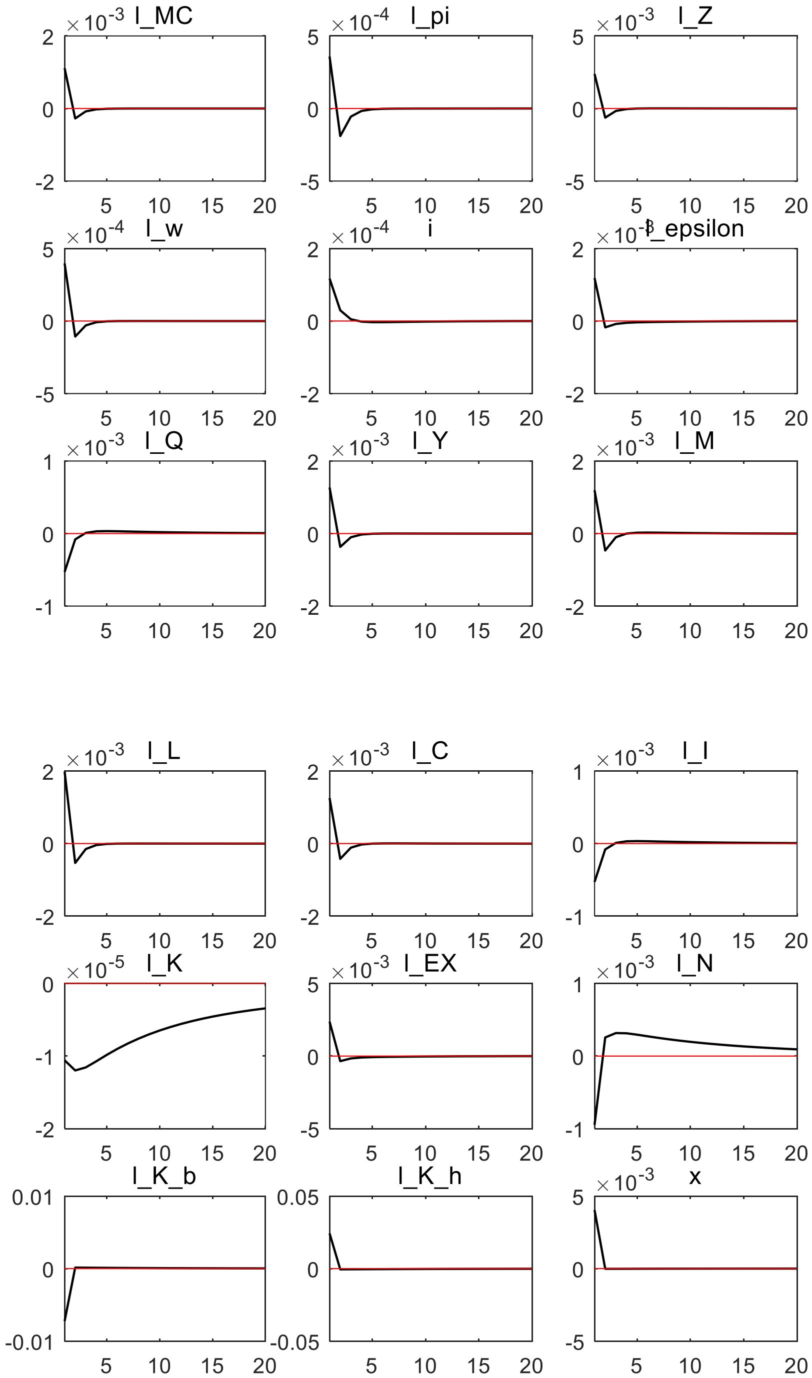
We also simulate the influence of the Central Bank intervention in the foreign exchange market, showing the effect of a 5% decline in the supply of foreign currency to the foreign exchange market by the Central Bank. Figure (5.6) shows the results.

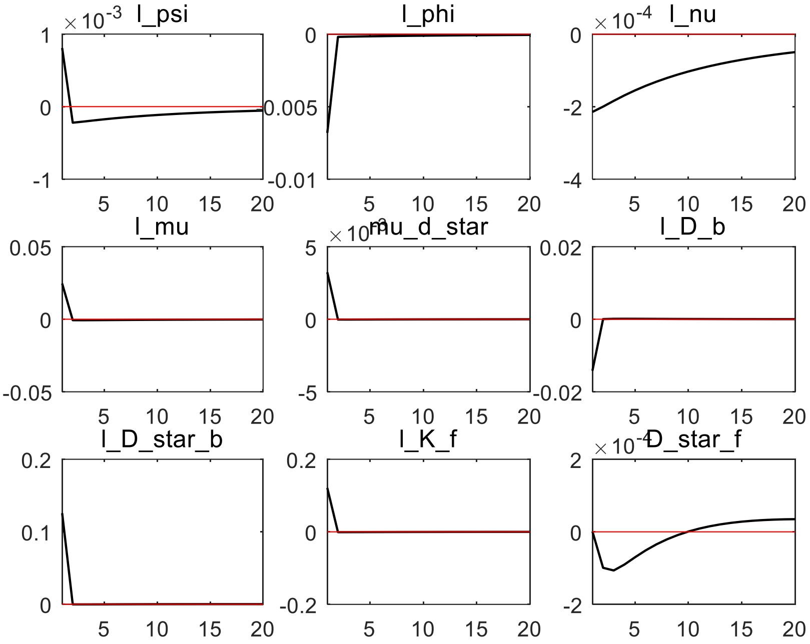
The decrease in foreign exchange market intervention causes a depreciated real exchange rate. Accordingly, exports, consumption and net output also increase. However, bank net worth decreases by 0.1% and asset prices decline by 0.05%. This reflects that the intervention using foreign reserve by the Central Bank can contribute to aggravate real activities through deteriorating financial intermediation to a certain degree.

However, when these two opposite effects are considered synthetically, it seems that appropriate foreign exchange intervention using foreign reserve by the Central Bank can be helpful in boosting inflation and output.

On the other hand, it also proves that as the intensity of the intervention is stronger, as the policy effectiveness is also bigger. Figure (5.7) demonstrates that the policy effectiveness is bigger when it is assumed that there exists positive 5% foreign reserve shock than when there is positive 1% foreign reserve shock.

<u>**Figure 5.6: IRFs to Foreign Reserve Policy**</u>




l_psi
l_phi
l_nu
l_mu
mu_d_star
l_D_b
l_D_star_b
l_K_f
D_star_f

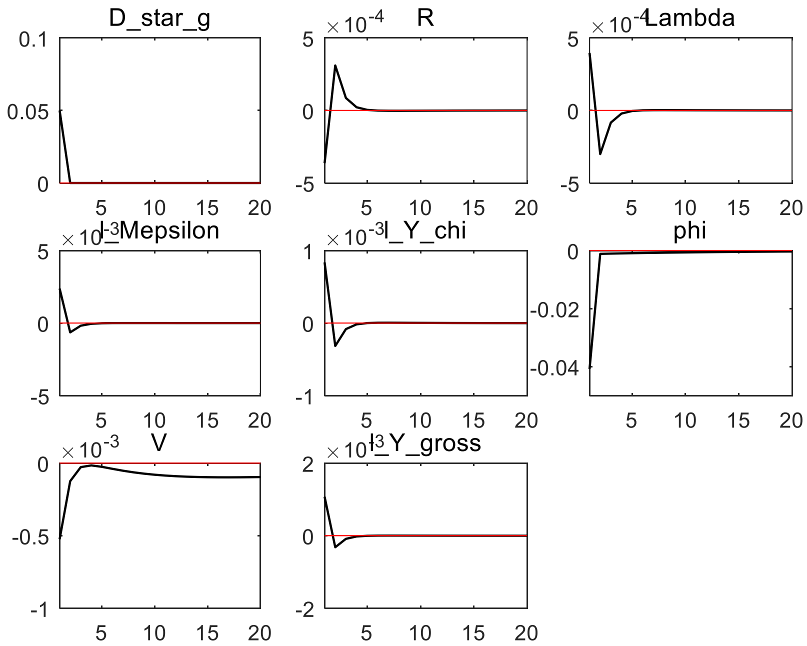
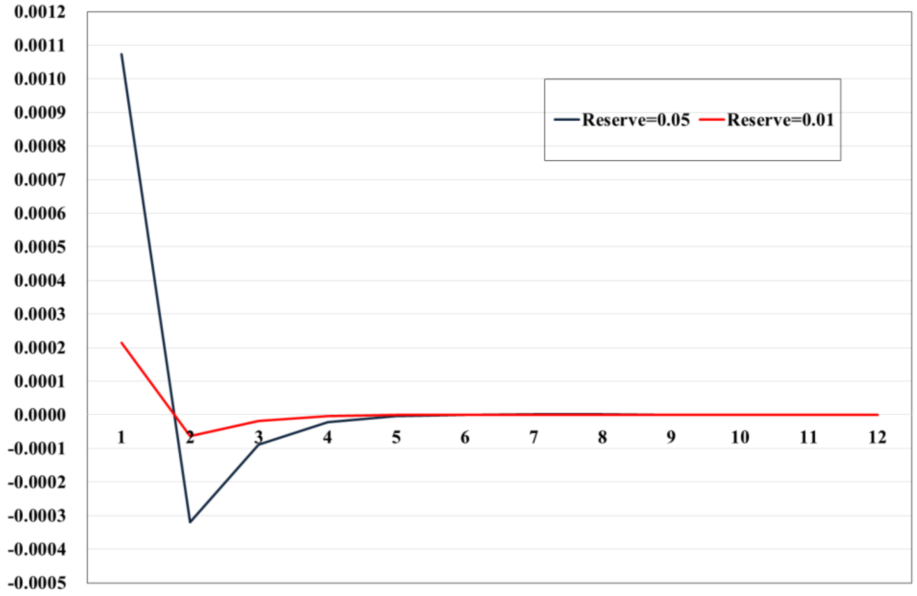
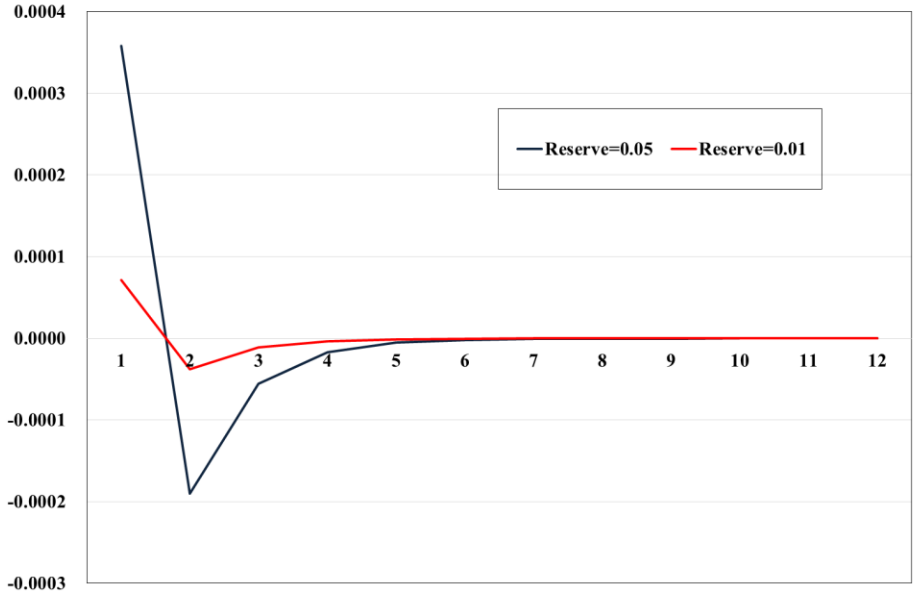

D_star_g
R
Lambda
l_Mepsilon
l_Y_chi
phi
V
l_Y_gross

Figure 5.7: Comparison of IRFs to Foreign Reserve Policy with Different Intensity

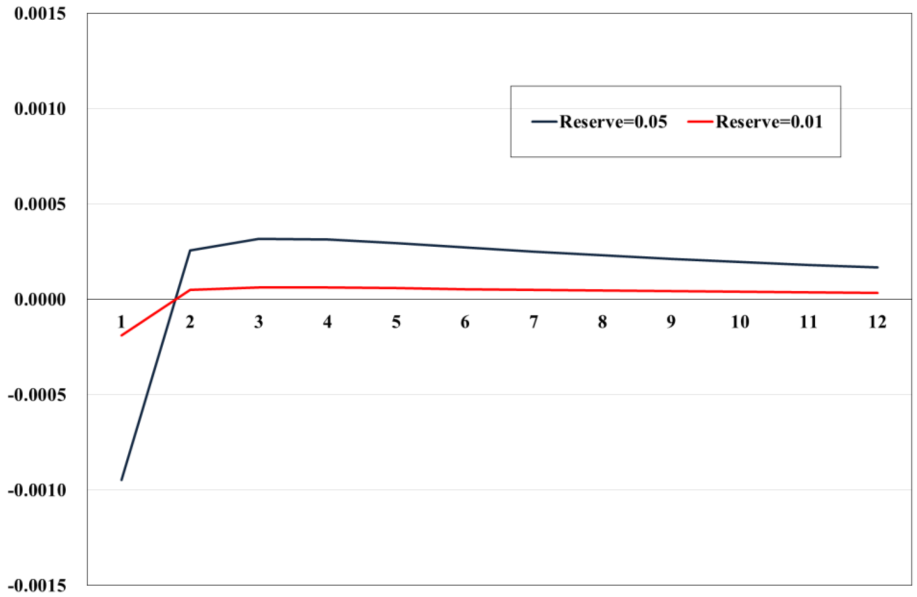
Output



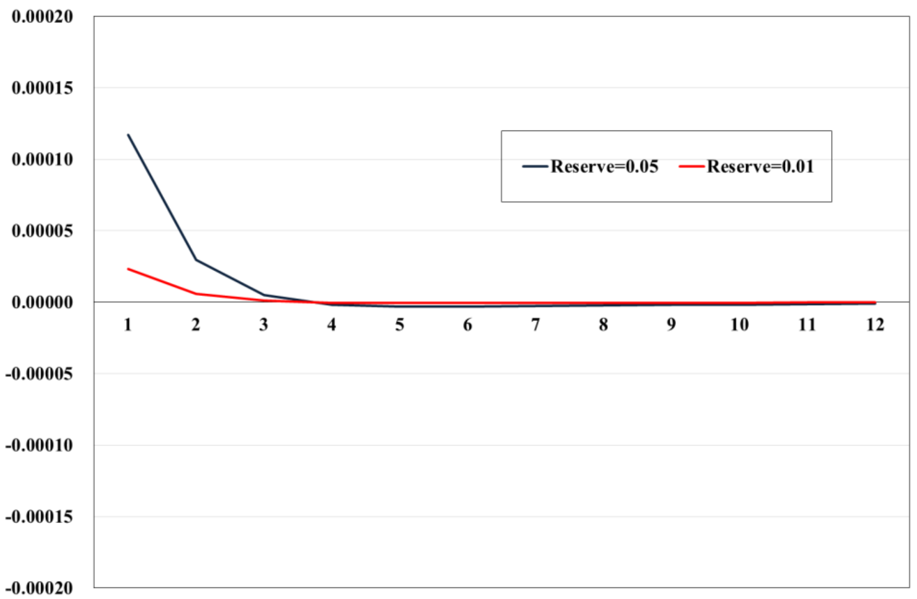
Inflation



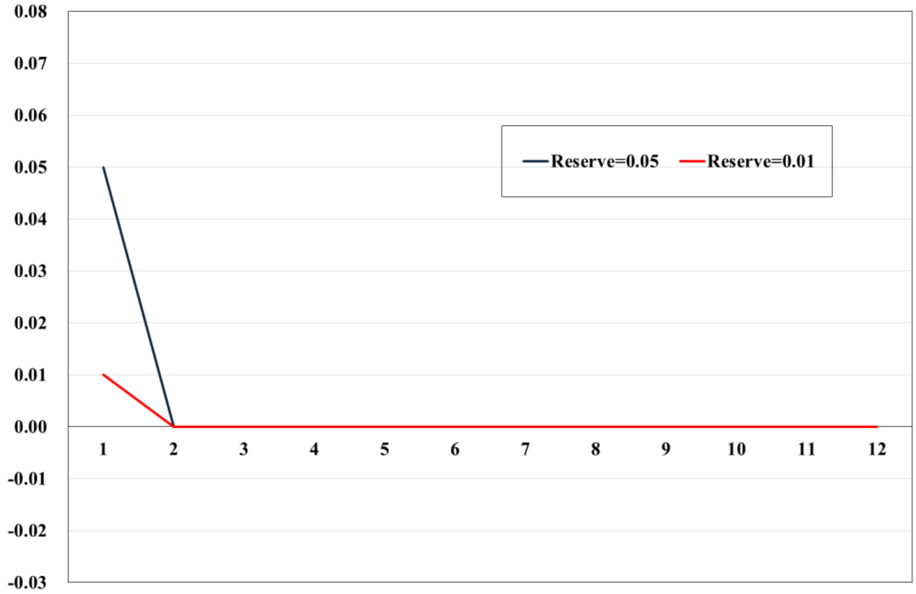
Bank Net Worth (Bank Capital)



Interest Rate



Foreign Reserve



5.3 Conclusion

In this chapter, we analyze the effectiveness of interest rate adjustment and foreign exchange market intervention based on such approach of Aoki, Benigno, and Kiyotaki (2016), who extend the model Gertler and Karadi (2011) to the open economy.

We also analyze the impact of shocks to total factor productivity (TFP), capital quality, and global interest rate. We investigate a positive TFP shock leads to an economic boom through its impact on consumption, exports and net output. Net output and consumption are boosted by more than 2%, while exports increase by more than 1.5%. On the other hand, real exchange rate depreciates by less than 1%. For other variables, inflation decreases by 0.5% and nominal interest rate decreases by 0.2%. This explains that because TFP shock occurs on supply side, inflation decreases and interest rate is lowered responding to such a falling inflation. In addition, investment and capital price increase by more than 2% and bank net worth rises by more than 1%.

The negative capital quality shock causes a negative effect on the economy, as it reduces effective capital, which in turn reduces bank capital and the price of capital. The exchange rate appreciates, leading to reduced exports and increased imports. In addition, inflation rises, leading to an increase in the policy rate. The net effect is to reduce consumption, investment and net output.

Finally, an increase in the global interest rate has ambiguous macroeconomic effects. Output and consumption increase following a real exchange rate depreciation. However, inflation and the policy rate increase. In addition, the price of capital falls, which, together with the depreciated real exchange rate, reduces bank net worth.

Meanwhile, when it comes to policy simulation, according to the impulse response functions to foreign reserve policy when the Central Bank lowers its foreign reserve supply into foreign exchange market by 5%, the real exchange rate depreciates. Then, export increases and consumption and net output also increase. On the other hand, in the financial sector, it proves that bank net worth decreases by 0.1% and asset price also declines by 0.05% due to depreciation. This reflects that the intervention using foreign reserve by the Central Bank can contribute to aggravate real activities through deteriorating financial intermediation to a certain degree.

However, when these two opposite effects are considered synthetically, it seems that appropriate foreign exchange intervention using foreign reserve by the Central Bank can be helpful in boosting inflation and output overall. Simultaneously, it also proves that as the intensity of intervention by the Central Bank is stronger, as the policy effectiveness is also bigger in the theoretic DSGE model.

Table 5.2: The Model Summary

Economic Agents	Equation
1. Households	
Euler equation	$1 = E_t\ (\Lambda_{t\ t+1} R_{t+1})$
First order condition	$1 = E_t\ [\Lambda_{t\ t+1} \frac{Z_{t+1} + (1-\delta)Q_{t+1}}{Q_t + f'(K_t^h)}]$
Labor supply	$w_t = \chi L_t^{\varphi}$
Equity price	$Q_t = 1 + \Sigma\left(\frac{I_t}{I}\right) + \left(\frac{I_t}{I}\right)\Sigma'\left(\frac{I_t}{I}\right)$
2. Banks	
Excess return on capital over domestic deposit	$u_t = E_t[\ \Lambda_{t\ t+1}(1-\theta+\theta\psi_{t+1})\left(\frac{Z_{t+1} + (1-\delta)Q_{t+1}}{Q_t} - R_{t+1}\right)]$
Cost advantage of debt denominated in the foreign currency over domestic deposit	$u_{d^*t} = E_t[\Lambda_{t\ t+1}(1-\theta+\theta\psi_{t+1})\left(R_{t+1} - \frac{\epsilon_{t+1}}{\epsilon_t} R_t^*\right)]$
Return on domestic deposit	$\nu_t = E_t[\Omega_{t\ t+1} R_{t+1}]$
Net worth evolution	$n_t = [Z_t + (1-\delta)Q_t]K_{t-1}^b - R_t D_{t-1} - \epsilon_t R_{t-1}^* D_{t-1}^*$
Balance sheet	$Q_t K_t^b = \phi_t n_t = N_t + D_t + \epsilon_t D_t^*$
Total capital	$K_t = K_t^b + K_t^h$
Capital accumulation	$K_t = (1-\delta)K_{t-1} + I_t$
3.Intermediate Good Producing Firms	
Production function	$Y_{mt} = A_t\left(\frac{\xi_t K_t}{\alpha_K}\right)^{\alpha_K}\left(\frac{M_t}{\alpha_M}\right)^{\alpha_M}\left(\frac{L_t}{1-\alpha_K-\alpha_M}\right)^{1-\alpha_K-\alpha_M}$
FOC through cost minimization	$\frac{w_t L_t}{Z_t \xi_t K_{t-1}} = \frac{1-\alpha_K-\alpha_M}{\alpha_K}$
FOC through cost minimization	$\frac{\epsilon_t M_t}{Z_t \xi_t K_{t-1}} = \frac{\alpha_M}{\alpha_K}$
4. Retail Firms	
Unit cost of production	$MC_t = \frac{1}{A_t}(z_t)^{\alpha_K}(\epsilon_t)^{\alpha_M}(w_t)^{1-\alpha_K-\alpha_M}$
Inflation dynamics	$\widehat{\pi_t} = \frac{\eta-1}{\kappa}\widehat{MC}_t + \beta E_t(\widehat{\pi_{t+1}})$
5. Small Open Economy	
Foreign debt	$D_t^* = R_{t-1}^* D_{t-1}^* + M_t - \frac{1}{\epsilon_t} EX_t$
Export function	$EX_t = \left(\frac{P_t}{e_t P_t^*}\right)^{-\varphi} Y_t^* = \epsilon_t{}^{\varphi} Y_t^*$
6. Monetary and Foreign Reserve Policy	
Interest rate policy rule	$i_t - i = (1-\rho_i)\varpi_\pi(\pi_t - 1) + \rho_i(i_{t-1} - i) + \varepsilon_t^i$
Foreign reserve policy rule	$FX_t - FX = (1-\rho_{FX})\varpi_{FX}(\epsilon_t - \epsilon) + \rho_{FX}(FX_{t-1} - FX) + \varepsilon_t^{FX}$
7. Other Equations	
Economy resource constraint	$Y_t = C_t + [1 + \frac{\varpi_I}{2}(\frac{I_t}{I})^2]\ I_t + EX_t + \frac{\kappa}{2}(\pi_t - 1)^2 Y_t - f(K_t^h)$
Nominal GDP	$Y_t^{GDP} = Y_t - \epsilon_t M_t$
Net output	$Y_t^n = Y_t - \epsilon_t M_t - \frac{\kappa}{2}(\pi_t - 1)^2 Y_t - f(K_t^h)$
Fisher equation	$1 + i_t = R_{t+1}\frac{E_t P_{t+1}}{P_t}$

Chapter 6. The Difference in Policy Effectiveness between Purchases of Private Securities and Long-Term Government Securities

6.1 The Model

6.1.1 Overview

In this chapter, I examine the effectiveness of an asset purchase program in Korea. As the policy rate of Bank of Korea recently approaches the effective lower bound, some arguments start to be suggested that Bank of Korea should also conduct unconventional monetary policy such as a large scale asset purchase which is similar to QEs in advanced economies to boost real activities. However, the theoretical difference in policy effectiveness of diverse asset purchase has not been discussed deeply in Korea. Considering this kind of insufficient research in Korea, in this chapter we analyze the difference of effectiveness between purchasing private and long-term government securities in terms of Gertler and Karadi (2013).

To do this, it is essential to model the difference in effectiveness of purchasing long-term government securities compared to purchasing private securities. In addition, it is also vital to examine the impact of zero lower bound on these purchases. In the study of Gertler and Karadi (2013), they examine the difference in policy effectiveness of asset purchases after dividing securities as private and long-term government securities and introduce the zero lower bound constraint. Therefore, I believe the approach of Gertler and Karadi (2013) is applicable in this chapter. This is an extension of Gertler and Karadi (2011) which is set in a closed economy. Gertler and Karadi (2013) investigate effects of asset purchase implemented in the U.S. in a period of the Great Recession. The authors reach three main conclusions. First, the framework they build is consistent with the existing evidence for large scale asset purchase. Second, purchases of private securities have more powerful effects than purchases of long-term government securities. Third, the effectiveness of asset purchases depends on whether short-term nominal rate is constrained to zero lower bound or not. In principle, it proves that these conclusions are applicable to Korea.

6.1.2 Households

Each household consumes goods, supplies labor and purchases financial assets. In each household, two kinds of members exist: a share $1-f$ are workers; the remainder are bankers. A current banker remains a banker in the subsequent term with probability θ; θ is not time variable. Hence, relative share of each sort does not change. $(1-\theta)f$ bankers become workers each period. A former banker gives his total assets to the household.

Household utility is separable in consumption and labor. It is

$$E_t \sum_{i=0}^{\infty} \beta^i [ln\,(C_{t+i} - \mu C_{t+i-1}) - \frac{\chi}{1+\varphi} L_{t+i}^{1+\varphi}] \tag{6.1}$$

where $0 < \beta < 1$, $0 < \mu < 1$, $\chi,\ \varphi > 0$. C_t represents household consumption and L_t is number of hours worked. Utility has external habit formation which is captured by parameter μ.

The household holds bank deposits and short-term government debt (in periods when this is issued). Deposits in banks and government debt are one-period riskless financial assets paying gross real return (R_t) from $t-1$ to t. Hence, they are perfect substitutes.

We denote household holdings of short-term debt by B. Then, the household budget constraint can be expressed as

$$C_t = W_t L_t + R_t B_{t-1} - B_t + T_t + \Pi_t - X \tag{6.2}$$

where W_t denotes the real wage, T_t are lump sum taxes, and Π_t is a payout to household ownership which contain both non-financial firms and banks. X represents a transfer the household supplies to members who become bankers.

The first order conditions regarding consumption and labor supply are

$$\varrho_t W_t = \chi L_t^{\varphi} \tag{6.3}$$

$$E_t \beta \Lambda_{t\,t+1} R_{t+1} = 1 \tag{6.4}$$

where the marginal utility of consumption is

$$\varrho_t = (C_t - \mu C_{t-1})^{-1} - \beta\mu E_t (C_t - \mu C_{t-1})^{-1} \tag{6.5}$$

and the stochastic discount rate is $\beta \Lambda_{t\,t+1}$ ($\Lambda_{t\,t+1} = \frac{\varrho_{t+1}}{\varrho_t}$).
In general, this part is same in the previous chapters.

6.1.3 Banks

Banks are competitive. They acquire funds from households' deposits at real interest rate (R_t). Then, they lend these to non-financial firms at stochastic lending rate (R_{kt}). They also hold long-term government securities having the real rate of return (R_{bt}). Therefore, banks perform maturity transformation.[13]

The financial assets of banks can be classified into two types. First, banks lend to nonfinancial firms who wish to fund their capital. Real rate of return on lending (R_{kt+1}) is

$$R_{kt+1} = \frac{Z_{t+1} + (1-\delta) Q_{t+1}}{Q_t} \xi_{t+1} \tag{6.6}$$

where Z_t is the net income flow to banks from a loan financing a unit capital, Q_t is the market value of security, δ represents the depreciation rate of capital per unit, ξ_{t+1} denotes a capital quality shock.

Second, banks also own long-term government securities. It is postulated each long-term government security is a perpetuity paying one dollar per period, indefinitely. The real rate of return on long-term

[13] It is assumed that short-term government securities are retained by households and long-term government securities are retained by banks. Here, I use the approach of Gertler and Karadi (2010) that it is costly for households to manage directly the portion of long-term government securities in their portfolios.

government security can be expressed as

$$R_{bt+1} = \frac{\frac{1}{P_t} + q_{t+1}}{q_t} \tag{6.7}$$

where q_t represents the price of a security and P_t denotes the price level.

In short, banks can hold both of private and long-term government securities. This changes the banks' behaviors in that banks can reflect their preferences in an asset purchase.

$The\ jth\ bank's\ \ balance\ sheet$:

$$Q_t S_{jt} + q_t B_{jt} = N_{jt} + D_{jt} \tag{6.8}$$

where S_{jt} is the amount lent by the bank to non-financial firms, q_t is the relative price of long-term government securities and B_{jt} represents the long-term government securities kept by the bank. N_{jt} represents the capital or net worth of bank. D_{jt} denotes the amount of deposits the bank acquires from households.

Therefore, the left-hand side shows the worth of bank's financial assets. On the other hand, the right-hand side is the worth of bank's liabilities. $Q_t S_{jt}$ is the loan portfolio of the bank and $q_t B_{jt}$ represents the long-term government bond portfolio of the bank. In this chapter, the composition of banks' balance sheet is different from those in the previous chapters in that long-term government securities are included.

$Bank\ net\ worth$:

$$N_{jt} = R_{kt} Q_{t-1} S_{jt-1} + R_{bt} q_{t-1} B_{jt-1} - R_t D_{jt-1} \tag{6.9}$$

Each individual bank's net worth or capital evolves as described by equation (6.9). It demonstrates that bank's net worth or equity capital is accumulated through retained earnings. Thus, the real return rate on loans or on long-term government securities influences bank net worth.

$Bank's\ objective$:

The bank's goal is to maximize the terminal net worth of the bank, which can be expressed as

$$V_{jt} = max\ \ E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i}(N_{jt+1+i}) \tag{6.10}$$

The bank's objective is the same as in previous chapters. However, in this chapter, the bank can hold a richer set of financial assets like private and long-term government securities.

(Agency Problem of Banks)

Similar to chapters 3, 4, and 5, perfect information is assumed between banks and firms. However, a moral hazard or costly enforcement problem between banks and depositors (households) is incorporated. The bank can divert some fraction of its financial assets and transfer diverted assets to the household of which he or she is a member. This agency problem is the same as in previous chapters.

$Incentive\ constraint\ of\ bank$:

$$V_{jt} \geq \lambda Q_t S_{jt} + \Omega\lambda q_t B_{jt} \tag{6.11}$$

The left-hand side represents the loss which the banker could face through diverting some fractions of their financial assets. Meanwhile, the right-hand side denotes benefit from diversion. It is assumed that the bank can divert funds from loans to non-financial companies more easily than funds from holdings of long-term government securities. It is modelled in that the banks can make illegal behaviors easier in managing private securities than long-term government securities because depositors can feel more difficult to keep watch for the performance of private securities than long-term government securities. In this regard, it is postulated that $0 \leq \Omega < 1$.

Equation (6.11) reflects the fact that the bank is subject to a limited commitment problem. The bank can only lend to firms and hold the long-term government securities when the payoff (V_{jt}) from lending and holding the long-term government securities is bigger than the utility from diverting assets ($\lambda Q_t S_{jt} + \Omega\lambda q_t B_{jt}$).

The approach to analyzing the bank's optimal behavior in this chapter is similar to the procedure used in chapter 3, 4, and 5. However, main difference with the previous chapters is introduction of long-term government security portfolio. In this chapter, by introducing long-term government securities, it makes it possible to analyze the difference in policy effectiveness between purchasing private and long-term government securities.

The bank's problem is more complex than in previous chapters. However, we will follow a similar approach. To solve bank's optimization problem, it is supposed that V_{jt} has the following functional form.

$$V_{jt} = V_{jt}(S_{jt}, B_{jt}, D_{jt}) = u_{st} S_{jt} + u_{bt} B_{jt} - u_{dt} D_{jt} \tag{6.12}$$

where u_{st}, u_{bt}, and u_{dt} denote time-varying marginal values of financial assets which bank holds in the end of each period. After removing D_{jt} using equation (6.8), the following equation can be derived.

$$\begin{aligned} V_{jt} = V_{jt}(S_{jt}, B_{jt}, N_{jt}) &= \nu_{1t} Q_t S_{jt} + \nu_{2t} q_t B_{jt} + u_{dt} N_{jt} \\ &= \nu_{1t} Q_t S_{jt} + \nu_{2t} q_t B_{jt} + \eta_t N_{jt} \end{aligned} \tag{6.13}$$

where $\nu_{1t} = \frac{u_{st}}{Q_t} - \eta_t$ represents the excess value of loans over deposits and $\nu_{2t} = \frac{u_{bt}}{q_t} - \eta_t$ is the excess value of holding long-term government securities over deposits. ν_{1t} represents the expected discounted marginal gain to the banker from extending loans to the non-financial firms by a unit, while maintaining bank capital N_{jt} unchanging. Similarly, ν_{2t} is the expected discounted marginal gain to the banker by expanding holdings of long-term government securities by a unit, while maintaining bank capital N_{jt} unchanging. η_t represents the expected discounted value of holding additional unit of N_{jt}, keeping S_{jt} and B_{jt} unchanging. ($u_{dt} = \eta_t$)

The Bellman equation for the bank's franchise value can be expressed as

$$V_{jt}\left(S_{jt}, B_{jt}, N_{jt}\right) = E_t \Lambda_{t,t+1}\{(1-\theta)N_{jt+1} + \theta\, max\, V_{jt+1}\left(S_{jt+1}, B_{jt+1}, N_{jt+1}\right)\} \tag{6.14}$$

In order to maximize this, we can solve the constrained optimisation problem.

$$\mathcal{L}_t = V_{jt} + \gamma_t\left(V_{jt} - \lambda Q_t S_{jt} - \Omega\lambda q_t B_{jt}\right) = (1+\gamma_t)V_{jt} - \lambda\gamma_t Q_t S_{jt} - \Omega\lambda\gamma_t q_t B_{jt} \tag{6.15}$$

where γ_t denotes the Lagrangian multiplier on the incentive constraint of the banks, where $\gamma_t > 0$ when the constraint binds and $\gamma_t = 0$ otherwise.

The first order conditions imply

$$\left[S_{jt}\right]\ \nu_{1t} = \lambda\frac{\gamma_t}{1+\gamma_t} = E_t\tilde{\Lambda}_{t,t+1}(R_{kt+1} - R_{t+1}) \tag{6.16}$$

$$\left[B_{jt}\right]\ \nu_{2t} = \Omega\lambda\frac{\gamma_t}{1+\gamma_t} = E_t\tilde{\Lambda}_{t,t+1}(R_{bt+1} - R_{t+1}) \tag{6.17}$$

$$V_{jt}\left(S_{jt}, B_{jt}, N_{jt}\right) = \nu_{1t}Q_t S_{jt} + \nu_{2t}q_t B_{jt} + \eta_t N_{jt} > \lambda Q_t S_{jt} + \Omega\lambda q_t B_{jt} \tag{6.18}$$

where $\tilde{\Lambda}_{t,t+1} = \Lambda_{t\ t+1}\Delta_{t+1}$, $\Delta_{t+1} = (1-\theta) + \theta\frac{\partial V_{t+1}}{\partial N_{t+1}}$, $\tilde{\Lambda}_{t,t+1}$ represents the augmented stochastic discount factor, $\Lambda_{t\ t+1}$ denotes the stochastic discount factor. Δ_{t+1} represents the multiplier.

Hence, the following equation can be derived. Equation (6.19) implies that the bank's portfolio size relative to its net worth is determined by the incentive constraint. When the asset measure in the bank's balance sheet constraint is calculated, Ω is applied to long-term government securities as a weight. This mirrors that weaker constraint on arbitrage is applied for long-term government securities than private securities.

$$Q_t S_{jt} + \Omega q_t B_{jt} = \phi_t N_{jt} \tag{6.19}$$

with $\phi_t = \frac{\eta_t}{\lambda - \nu_{1t}}$

<u>Figure 6.1: The Commercial Bank Balance Sheet</u>

Assets	Liabilities
Loan Portfolio ($Q_t S_t$)	Deposits (D_t)
Long-Term Government Security Portfolio ($q_t B_t$)	Capital or Net Worth (N_t)

(Aggregate Net Worth of Banks)

Banks' total capital is equivalent to sum of existing bankers' capital (N_{et}) and newly entering bankers' capital (N_{nt}).

$Law\ of\ motion\ for\ aggregate\ bank\ net\ worth$:

$$N_t = N_{et} + N_{nt} \tag{6.20}$$

Since a fraction θ of banks in time *t* will remain alive until *t*+1, the capital of existing bankers is

$$N_{et} = \theta[(R_{kt} - R_t)\frac{Q_{t-1}S_{t-1}}{N_{t-1}} + (R_{bt} - R_t)\frac{q_{t-1}B_{t-1}}{N_{t-1}} + R_t]N_{t-1} \tag{6.21}$$

The household transfers ω of total bank capital. Hence, new banker's capital is given by

$$N_{nt} = \omega Q_t S_{t-1} \tag{6.22}$$

where $0 < \omega < 1$

6.1.4 Intermediate Good Firms

The model structure in this part is the same with Gertler and Karadi (2011). There exist many firms producing intermediate goods under perfect competition. These firms obtain capital from banks to produce intermediate products, which they sell to final goods firms.

To finance their purchase of capital, intermediate goods firms issue equity which they sell to commercial banks. Capital value is equivalent to financial claims value. In other words, intermediate goods producers finance their capital acquisition for next period K_{t+1} by borrowing the amount S_t, where, through arbitrage,

$$Q_t K_{t+1} = Q_t S_t \tag{6.23}$$

Intermediate goods producing firms produce output (Y_{mt}) with capital and labor as inputs. They can also change the utilization rate (Z_t). The production technology is assumed to be

$$Y_{mt} = A_t(Z_t \xi_t K_t)^{\alpha} {L_t}^{1-\alpha} \tag{6.24}$$

where A_t denotes total factor productivity, ξ_t represents a shock to capital quality which provides a exogenous source for the variation in capital value. Accordingly, $\xi_t K_t$ is effective quantity of capital. Z_t represents utilization rate of capital. An additional assumption is that the cost of capital replacement is fixed and equivalent to unity. Then, the optimization problem of intermediate goods firms is

$$\max_{L_t,\ Z_t}\ P_{mt}Y_{mt} + [Q_t - \delta(Z_t)]\xi_t K_t - W_t L_t - R_{kt}Q_{t-1}K_t \tag{6.25}$$

where P_{mt} is relative price of intermediate goods, δ denotes the depreciation rate of capital which is a function of utilization rate.

$$\delta(Z_t) = \delta_c + \frac{b}{1+\zeta} Z_t^{1+\zeta} \tag{6.26}$$

where ζ represents the depreciation elasticity in regard to utilization rate.

The first order conditions for labor demand and utilization rate can be expressed as

$$P_{mt}(1-\alpha)\frac{Y_{mt}}{L_t} = W_t \tag{6.27}$$

$$P_{mt}\alpha\frac{Y_{mt}}{Z_t} = \delta'(Z_t)K_t\xi_t \tag{6.28}$$

In addition, gross profits per unit of capital are given by

$$P_{mt}\alpha\frac{Y_{mt}}{K_t} = Z_t \tag{6.29}$$

Differentiating (6.28) with respect to K_{t+1} gives

$$R_{k\,t+1} = \frac{[\,P_{mt+1}\,\alpha\frac{Y_{m\,t+1}}{\xi_{t+1}K_{t+1}} + Q_{t+1} - \delta(Z_{t+1})\,]\,\xi_{t+1}}{Q_t} \tag{6.30}$$

Equation (6.30) shows that the return on bank's lending to intermediate goods firms is equivalent to the ex post return to capital. This is because the intermediate goods market is competitive.

6.1.5 Capital Producing Firms

The model structure in this part is the same as in the previous chapters. The capital goods market is also competitive. In the end of each term, firms producing capital goods purchase capital from firms producing intermediate products. After capital producers fix depreciated capital, they create new capital. Then, the capital producers sell new capital to intermediate goods producers. It is assumed replacing cost for deteriorated capital is equal to unity. The unit value of newly refurbished capital is equivalent to Q_t. There also exist flow adjustment costs relating to creating new capital given by $I_{n\tau} \equiv I_t - \delta(Z_t)\,\xi_t K_t$. $I_{n\tau}$ is net amount of new capital created and I_{ss} represents investment in steady state.

$$max\ \ E_t \sum_{\tau=t}^{\infty} \beta^{T-\tau} \Lambda_{t,\tau}\,[(Q_\tau - 1)I_{n\tau} - \Xi(\frac{I_{n\tau}+I_{ss}}{I_{n\tau-1}+I_{ss}})(I_{n\tau} + I_{ss})] \tag{6.31}$$

where I_t is gross capital created. Equation (6.31) represents discounted profits for a capital producer. The function $\Xi(\cdot)$ captures capital adjustment cost, where $\Xi(1) = \Xi'(1) = 0$, and $\Xi''(1) > 0$.

The first order condition for investment gives

$$Q_t = 1 + \Xi(\cdot) + \frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}}\Xi'(\cdot) - E_t[\Lambda_{t,t+1}(\frac{I_{nt+1}+I_{ss}}{I_{nt}+I_{ss}})^2\Xi'(\cdot)] \tag{6.32}$$

6.1.6 Retail Firms

This part is also the same as in the previous chapters. As in other New Keynesian models, retail firms are introduced to add nominal rigidities into the model. There exist a continuum of firms producing final goods who costlessly differentiate intermediate goods into their own final goods, and sell these final goods under monopolistic and competitive market.

Final product consumed by households is considered as a composite of the final products produced by individual retail firms.

$$Y_t = [\int_0^1 Y_{ft}^{\frac{\varepsilon-1}{\varepsilon}} df]^{\frac{\varepsilon}{\varepsilon-1}} \tag{6.33}$$

where Y_{ft} is output by retailer f and Y_t is total final output. ε is substitution elasticity between individual final products in the composition of final output (ε > 1).

The demand for individual final good is

$$Y_{ft} = \left(\frac{P_{ft}}{P_t}\right)^{-\varepsilon} Y_t \tag{6.34}$$

where the aggregate price level is

$$P_t = [\int_0^1 P_{ft}^{1-\varepsilon} df]^{\frac{\varepsilon}{1-\varepsilon}} \tag{6.35}$$

Retailers choose their optimal price (P_t^*) to maximize their profits.

$$max \ E_t \sum_{\tau=t}^{\infty} \gamma^\tau \beta^\tau \Lambda_{t,t+\tau} [\frac{P_t^*}{P_{t+\tau}} \prod_{k=1}^{\tau} (1+\pi_{t+k-1})^{\gamma_p} - P_{m\ t+\tau}] Y_{f\ t+\tau} \tag{6.36}$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ represents gross inflation rate.

The first order condition is derived as

$$E_t \sum_{\tau=t}^{\infty} \gamma^\tau \beta^\tau \Lambda_{t,t+\tau} \left[\frac{P_t^*}{P_{t+\tau}} \prod_{k=1}^{\tau} (1+\pi_{t+k-1})^{\gamma_p} - \frac{1}{1-\frac{1}{\varepsilon}} P_{m\ t+\tau}\right] Y_{f\ t+\tau} = 0 \tag{6.37}$$

This implies

$$P_t^{1-\varepsilon} = \gamma(\pi_{t-1}^{\gamma_p} P_{t-1})^{1-\varepsilon} + (1-\gamma)(P_t^*)^{1-\varepsilon} \tag{6.38}$$

This implies that inflation dynamics are given by

$$\pi_t^{1-\varepsilon} = \gamma \pi_{t-1}^{\gamma_p(1-\varepsilon)} + (1-\gamma)(\pi_t^*)^{1-\varepsilon} \tag{6.39}$$

6.1.7 Monetary and Credit Policies

(Monetary Policy)

Monetary policy is incorporated as the same way in the previous chapters. Monetary policy objective is to stabilize inflation and output. It is supposed the Central Bank adjusts risk free nominal rate (i_t) paid on household's deposits following a traditional Taylor rule.

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)[\kappa_\pi \pi_t + \kappa_y (logY_t - logY^*)] + \varepsilon_t \tag{6.40}$$

where i_t is risk-free nominal rate. κ_π represents policy reaction to inflation and κ_y represents policy reaction to output gap. ρ_i is smoothing operator. ε_t denotes interest rate shock following an AR(1) process.

By Fisher Equation, connection between real and nominal interest rate is expressed as

$$1 + i_t = R_{t+1} \frac{P_{t+1}}{P_t} \tag{6.41}$$

(Credit Policy)

When crises arise, credit spreads rise sharply. In this kind of environment, I postulate the Central Bank supplies credit in response to the credit spreads in private securities or long-term government securities. They do so through large scale asset purchases.

In regard to credit policy, it is supposed the Central Bank purchases some proportions (ϖ_{st} and ϖ_{bt}) of the outstanding stocks of private securities and long-term government securities. This setting is different from previous chapters in that it is assumed in the previous chapters that the Central Bank supplies credit in reaction to changes of the credit spread relative to steady state value. Referring to US quantitative easing, S_{gt} and B_{gt} in this part can be considered as private securities such as MBS and treasury bond purchased by the Central Bank, respectively.

$$S_{gt} = \varpi_{st} S_t \tag{6.42}$$

$$B_{gt} = \varpi_{bt} B_t \tag{6.43}$$

where it is assumed that ϖ_{st} and ϖ_{bt} follow second order stationary stochastic processes.

In order to fund asset purchases, it is assumed that the Central Bank issues riskless short-term debt (D_{gt}) paying risk-free interest rate (R_{t+1}) which are purchased by households.

Thus, the balance sheet of the Central Bank is

$$Q_t S_{gt} + q_t B_{gt} = D_{gt} \tag{6.44}$$

In addition, because the Central Bank is assumed not to be as efficient as commercial banks in financial intermediation, it is postulated that the Central Bank pays some efficiency costs, τ_s for loans and τ_b for government securities. In general, it is regarded that commercial banks are more specialized in lending procedure than the Central Bank because they have more detailed information about the financial status of borrowers.

In equation (6.44), D_{gt} is riskless short-term debt issued by the Central Bank. As long as interest-bearing reserves and short-term government securities are close substitutes, large scale asset purchase financed by interest-bearing reserve can be considered to be equivalent to large scale asset purchase financed by selling some holdings of short-term government securities when it comes to policy effectiveness. Therefore, the finance through short-term government securities can be interpreted as the finance through interest-bearing reserve[14] in this chapter.

Therefore, in some economic states where financial intermediation cannot be conducted efficiently due to disruption in the credit market, the Central Bank can intervene in the credit market directly by furnishing Central Bank money into the very short-term reserve market. In this case, different from private financial intermediation, the Central Bank is able to inject funds without any limit because it can issue short-term liabilities without limit. In other words, for the Central Bank, there is no agency conflict. This represents the idea that during some huge financial crisis, the intermediation by the Central Bank can be critical in normalizing the financial market and boosting real activity because the Central Bank, unlike commercial banks, is not balance-sheet restricted.

The total quantities of loans and long-term government securities are

$$S_{pt} + S_{gt} = S_t \tag{6.45}$$

$$B_{pt} + B_{gt} = B_t \tag{6.46}$$

where S_{pt} and B_{pt} represents loans and holding long-term government securities by private intermediation, respectively. On the other hand, S_{gt} and B_{gt} denotes loans and long-term government securities which the Central Bank holds, respectively.

<u>Figure 6.2: The Central Bank Balance Sheet</u>

Assets	Liabilities
Loan $(Q_t S_{gt})$	Debt (D_{gt})
Long-Term Government Security $(q_t B_{gt})$	

[14] Reserves are deposits held by commercial banks at the Central Bank.

6.1.8 Resource Constraint

Final output is composed of consumption, investment, investment adjustment costs, government consumption, and expenditures (Γ_t) incurred from the Central Bank's intermediation in the financial market. Thus, the economy-wide resource constraint is described as

$$Y_t = C_t + I_t + \Xi(\frac{I_t}{I_{t-1}}) I_t + G + \Gamma_t \tag{6.47}$$

where $\Gamma_t = \tau_s Q_{t-1} S_{gt-1} + \tau_b q_{t-1} B_{gt-1}$, τ_s and τ_b are efficiency costs relating to the Central Bank's intervention, respectively for loans and holding long-term government securities.

Next, the supply of private securities is equivalent to the sum of newly obtained capital (I_t) and remaining capital [$(1-\delta)K_t$] in the end of period t.

$$S_t = (1-\delta)K_t + I_t \tag{6.48}$$

Finally, it is also assumed that the government fixes the supply of long-term government securities.

$$B_t = B \tag{6.49}$$

6.1.9 Allowing for Households to Maintain Private Securities or Long-Term Government Securities

In this section, it is additionally postulated that households can hold not only long-term government securities but also private securities. Households can be restricted because households have to pay transaction costs when they hold both private and government securities.

Holding costs relating to private or long-term government securities can be assumed respectively as follow. Households are able to maintain a certain amount[15] of private and long-term government securities without cost. However, if households purchase more private and long-term government securities than steady state values, they have to pay transaction cost which are marginally increasing. Through this transaction cost, limited participation of households can be introduced into the model.

$$\textit{Holding cost for private securities: } \frac{1}{2}\kappa\frac{(S_{ht}-S_h)^2}{S_{ht}} \tag{6.50}$$

where $S_{ht} > S_h$, S_h is value of households' private securities holding in the steady-state.

$$\textit{Holding cost for long-term government securities: } \frac{1}{2}\kappa\frac{(B_{ht}-B_h)^2}{B_{ht}} \tag{6.51}$$

where $B_{ht} > B_h$, B_h is value of households' long-term government securities holding in the steady-state.

According to equation (6.50) and (6.51), even though households can keep some amount of private or long-term government securities without any cost, they face transaction costs which have increasing function at the margin above the minimum level. Hence, when considering this type of households' holding for private or long-term government securities based on incomplete arbitrage, the budget constraint of households in the previous subsection changes to be

$$\begin{aligned} C_t + D_{ht} + Q_t\left[S_{ht} + \frac{1}{2}\kappa(S_{ht}-S_h)^2\right] + q_t\left[B_{ht} + \frac{1}{2}\kappa(B_{ht}-B_h)^2\right] \\ = W_tL_t + R_tD_{ht-1} + R_{bt}B_{ht-1} + R_{kt}S_{ht-1} + T_t + \Pi_t \end{aligned} \tag{6.52}$$

As a result of household's optimization, the following equations for private and long-term government securities are derived.

$$S_{ht} = S_h + \frac{E_t\Lambda_{t,t+1}(R_{kt+1}-R_{t+1})}{\kappa} \tag{6.53}$$

$$B_{ht} = B_h + \frac{E_t\Lambda_{t,t+1}(R_{bt+1}-R_{t+1})}{\kappa} \tag{6.54}$$

The demands for private securities (S_{ht}) and long-term government securities (B_{ht}) are increasing in excess return relative to the curvature parameter (κ) with respect to the marginal transaction cost. In other words, according to the change of marginal transaction cost, demands in private and long-term government securities also change.

[15] S_h and B_h

Next, through allowing households to maintain private or long-term government securities, the equilibrium conditions for private or long-term government securities in the previous subsection also change as follow.

$$S_{pt} + S_{gt} + S_{ht} = S_t \tag{6.55}$$

$$B_{pt} + B_{gt} + B_{ht} = B_t \tag{6.56}$$

In addition, the aggregate portfolio constraint of bank also changes by allowing for households directly to hold private or long-term government securities in their portfolio.

$$Q_t(S_t - S_{ht}) \leq \phi_t N_t + Q_t S_{gt} + \Omega q_t [B_{gt} - (B_t - B_{ht})] \tag{6.57}$$

Therefore, for the large scale asset purchase program of the Central Bank to be effective through the adjustment of asset prices and excess returns, the limits for arbitrage for households and banks should be also postulated.

6.2 Empirical Results

6.2.1 Calibration

In this model, the number of parameters is 20. Among those parameters, 12 parameters are standard. On the other hand, 8 parameters are additionally included in this model compared to traditional models. Those newly included parameters are θ, σ, Ω, W, κ, S_h, B_h, B.

With regard to setting of parameter values, in order to represent macroeconomic characteristics of Korea appropriately, some parameters are calibrated similarly to chapters 3 and 4. Steady-state, average values of recent time-series data, and related literatures are variously used in calibrating parameters. When it comes to this process, some parameter values in chapters 3 and 4 are consistently used if they are still related with this modified model.

In addition, regarding to some coefficients in standard Taylor rule, traditional values are used. Coefficient on inflation is determined as 1.5. Meanwhile, negative value of price markup is used for output term in standard Taylor rule. In addition, the smoothing parameter in the Taylor rule is 0.782 following chapters 3 and 4.

Finally, for other additional parameters in this model, annual average values for Korea from 2009 to 2015 are used for the steady-state values of long-term government security supply, proportion of direct capital held by household, and the proportion of long-term government security held by households. There is consensus on that Korean economy has faced structural change since the Global Financial Crisis in 2008. Therefore, the statistics before 2009 are not used in the calibration. Relating to proportional advantage in government security's seizure rate or portfolio adjustment cost, the original values in Gertler and Karadi (2013) are used.

<u>Table 6.1: Calibrated Parameters</u>

Parameters	Description	Value		Parameters	Description	Value	
		Korea	GK[16]			Korea	GK
β	Discount factor	0.995	0.995	ζ	Elasticity of marginal depreciation in utilization rate	7.200	7.200
μ	Habit persistence parameter	0.815	0.815	η_i	Inverse elasticity of net investment to capital value	1.728	1.728
χ	Relative utility weight of labor	**<u>12.00</u>**	**<u>3.482</u>**	ε	Substitution elasticity in goods	4.167	4.167
φ	Inverse Frisch elasticity in labor supply	0.276	0.276	γ	Probability of maintaining prices fixed	0.779	0.779
λ	Diverting fraction of capital	0.345	0.345	γ_p	Measure of price indexation	0.241	0.241
ω	Transfer to entering bankers	0.0007	0.0007	κ_π	Inflation coefficient in Taylor rule	1.500	1.500
θ	Survival rate of bankers	0.972	0.972	κ_y	Output gap coefficient in Taylor rule	**<u>-0.500</u>**	**<u>-0.125</u>**[17]
α	Effective capital Share	**<u>0.400</u>**	**<u>0.330</u>**	ρ_i	Smoothing parameter in Taylor rule	**<u>0.782</u>**	**<u>0.000</u>**
Z	Capital utilization rate of steady state	1.000	1.000	G/Y	Government's expenditure/GDP ratio in the steady state	**<u>0.137</u>**	**<u>0.200</u>**
δ	Depreciation rate in the steady state	**<u>0.020</u>**	**<u>0.025</u>**				
< Additional Parameters in GK (2013) Model >							
Ω	Proportional advantage in seizure rate of government security	0.500	0.500	K_h/K	Ratio of direct capital holdings in household	**<u>0.158</u>**	**<u>0.500</u>**
B/Y	Government security supply in the steady state	**<u>0.263</u>**	**<u>0.450</u>**	B_h/B	Ratio of long-term government security holdings in household	**<u>0.040</u>**	**<u>0.750</u>**
κ	Portfolio adjustment cost	1.000	1.000				

16 Gertler and Karadi (2013)

17 As a proxy for output gap, the negative value of price markup is used.

6.2.2 Experiment

In this policy experiment, it is supposed the Central Bank can purchase not only long-term government securities but also private securities in response to credit market state. Hence, the composition of the asset purchase implemented by the Central Bank is not identical compared to such policies discussed in chapter 3 and 4. In chapter 3 and 4, it was simply assumed the Central Bank was able to purchase just government securities, not private securities.

Basically, it is postulated the intensity of asset purchases in the securities market depends on risk premium, regardless of whether they are long-term government securities or private securities. In regard to feedback parameters in the credit policy rule, the feedback parameter for purchasing private securities is set as ν_k and feedback parameter for purchasing long-term government securities is ν_B, respectively. In addition, the values for feedback parameter such as ν_k and ν_B are both set as 10, to consider same degree of the Central Bank's intervention. When feedback parameter is set as 10, it usually represents that it is closer to a real economic condition. Under this condition, the share of cumulative purchase by the Central Bank is set as three percent of GDP in both cases.

During the Global Financial Crisis, European Central Bank (ECB) initially purchased securities which was equivalent to about 2.4% of annual GDP in its Securities Markets Programme (SMP). They implemented such asset purchase policy in terms of supporting traditional interest rate policy as a complement, not as a substitute. Reflecting on this case, we establish the cumulative intensity in intervention for private or long-term government securities market as 3% of annual GDP.

With regard to zero lower bound, it is postulated adjustment of the policy rate by the Central Bank is restricted near zero lower bound for first consecutive four quarters. After the consecutive four quarters, the policy rate is assumed to flexibly fluctuate according to traditional Taylor rule set in the model. In addition, the portfolio adjustment cost of the household is fixed as unity following the approach of Gertler and Karadi (2013). They argue that when the portfolio adjustment cost is unity, simulation of the model approximates the real effects of QE2 well.

(Difference in Policy Effectiveness between Purchasing Private Securities and Long-Term Government Securities)

Policy simulations suggest purchase of private securities by the Central Bank can be more effective than purchase of long-term government securities in stabilizing some financial market distress and boosting real activities when it is assumed that the feedback parameters of the two types of purchases are same ($\nu_k = \nu_B = 10$).

The concrete outcome of simulation is reported in the figure (6.3). The blue line reports the response to purchase of private securities. On the other hand, the red line demonstrates reaction to purchase of long-term government securities. According to such simulation results, purchases of both private and long-term government securities make contributions in boosting output and inflation. Both purchases are useful in reducing risk premium or excess return of each security, then it triggers to raise the asset price and the net worth of banks. Finally, both large-scale asset purchases contribute to recover the negative impacts of economic crisis.

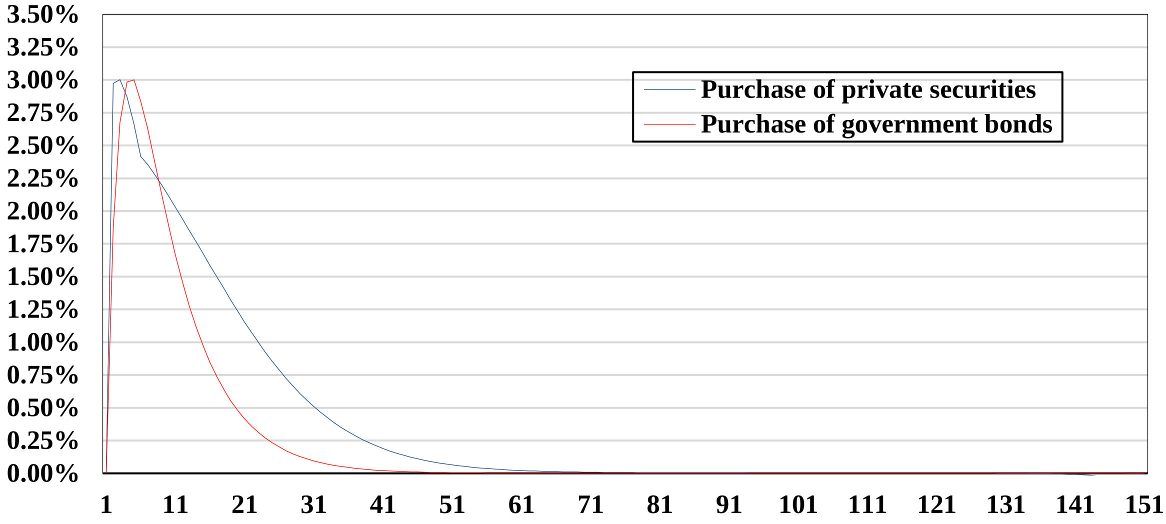
However, according to the simulations, in terms of policy effectiveness, similar sized asset purchases for long-term government securities or private securities affect real and financial economy to different degree. In other words, it turns out that if the intensity of intervention is similar, purchasing private securities can be more effective in boosting real activities and inflation than purchasing same amount of long-term government securities. Figure (6.3) proves the policy effectiveness for purchasing private securities is larger than purchasing long-term government securities in changes of spread, asset price, bank net worth, inflation, and output.

These results reflect that when the Central Bank purchases private securities, the balance sheet of the banks can be more relaxed compared to when purchasing long-term government securities. This kind of purchase of private securities can be contributed to increasing the market demand for private securities successively.

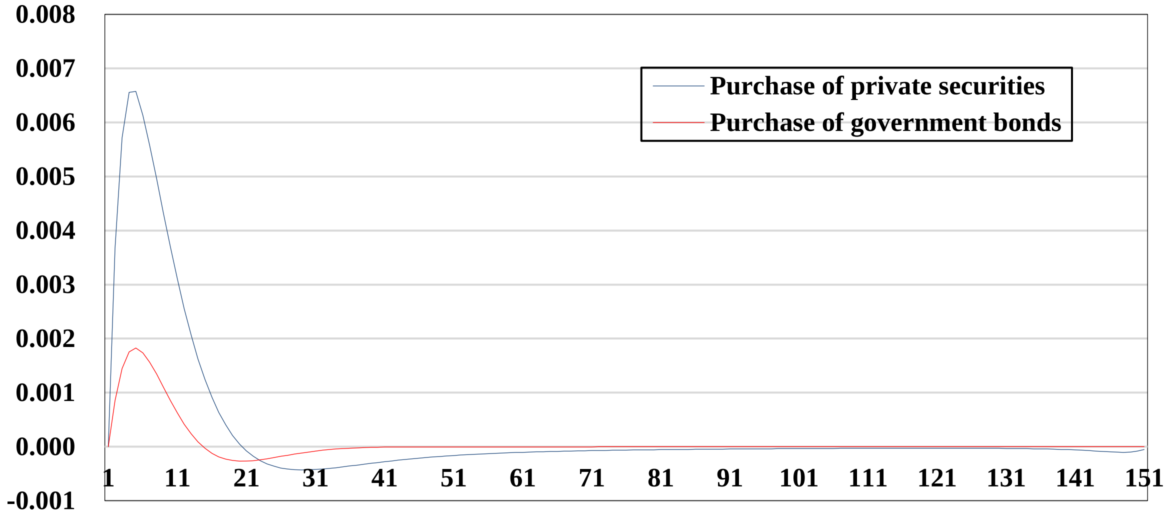
Figure 6.3: Difference in Policy Effectiveness

between Purchasing Private Securities and Long-Term Government Securities

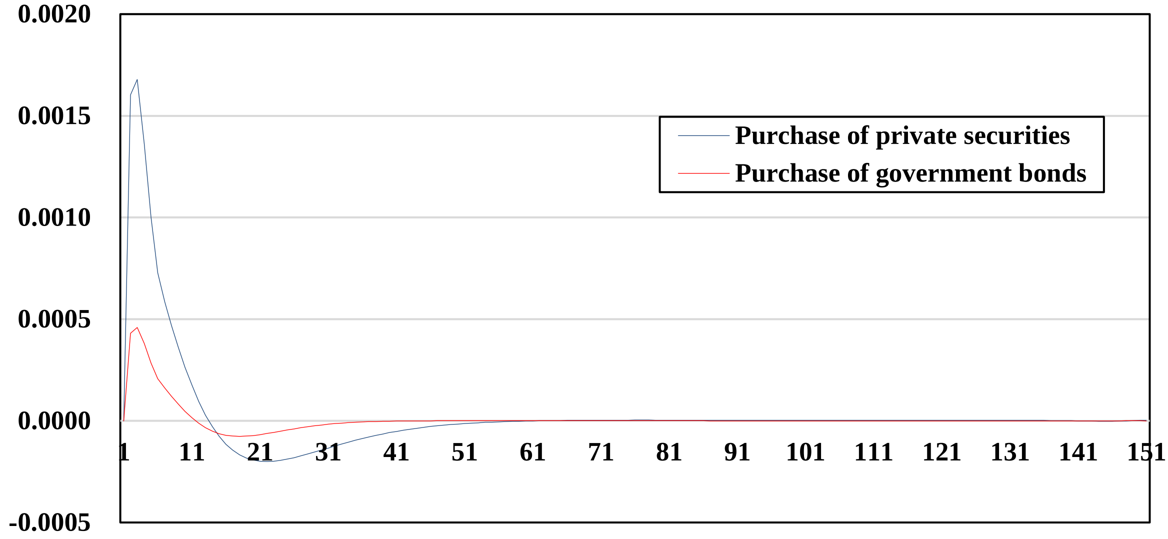
Share of Purchase per GDP



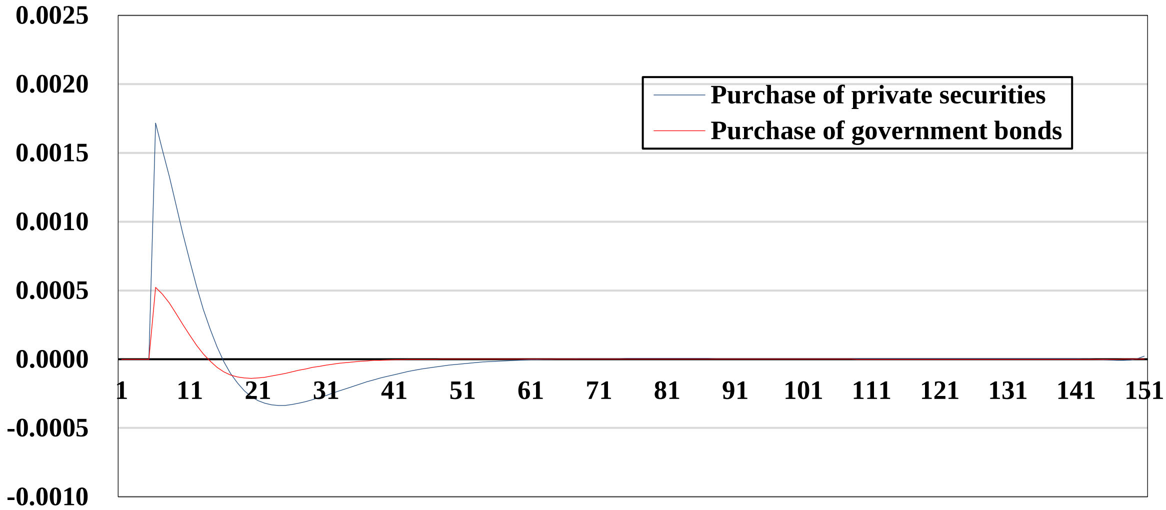
Output



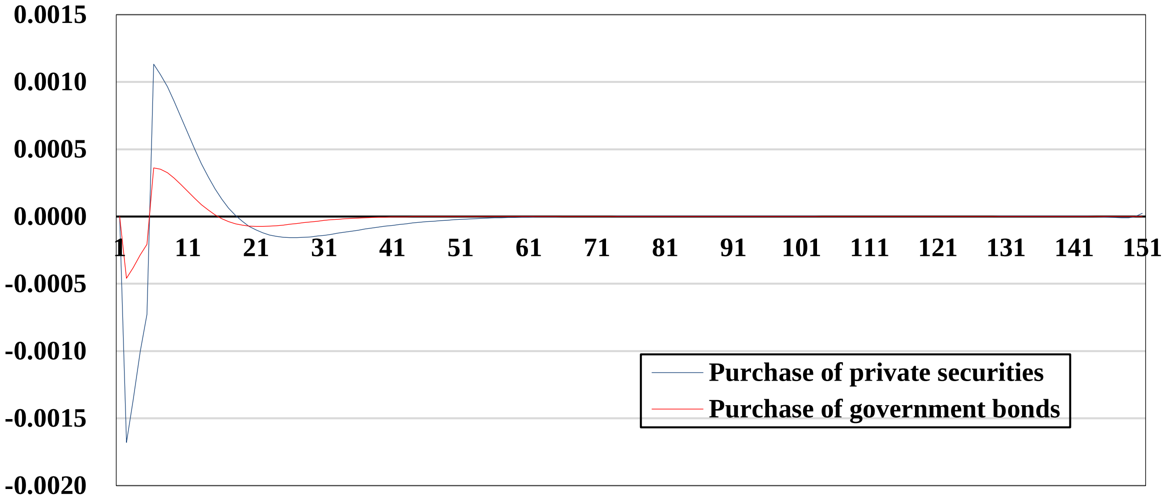
Inflation



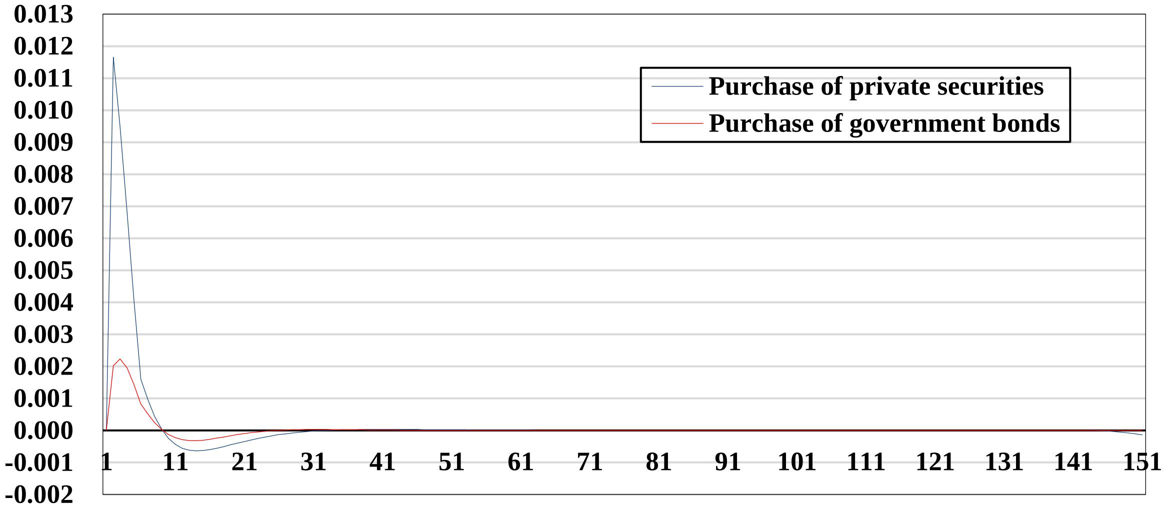
Nominal Policy Rate



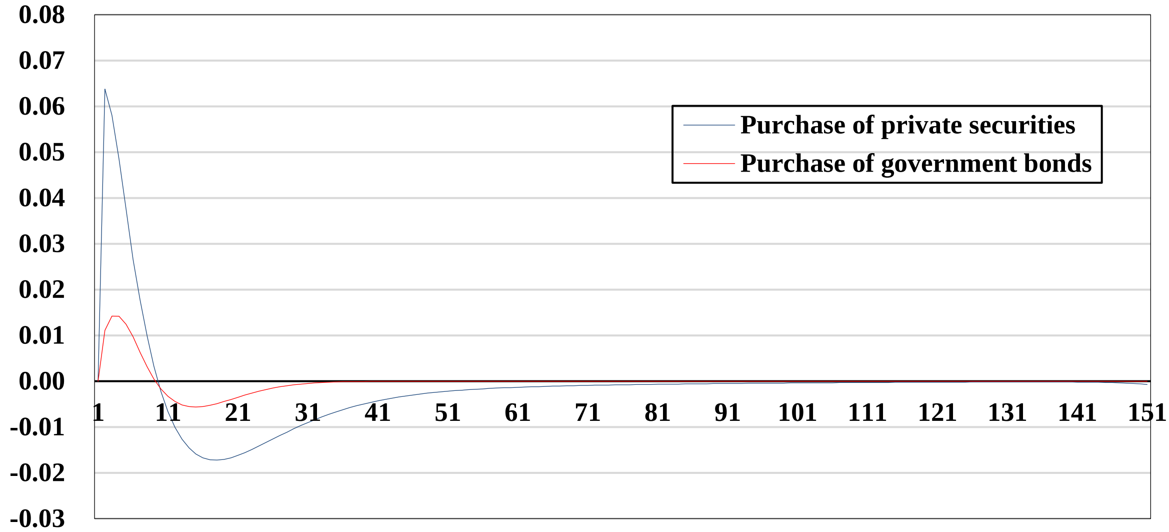
Deposit Rate



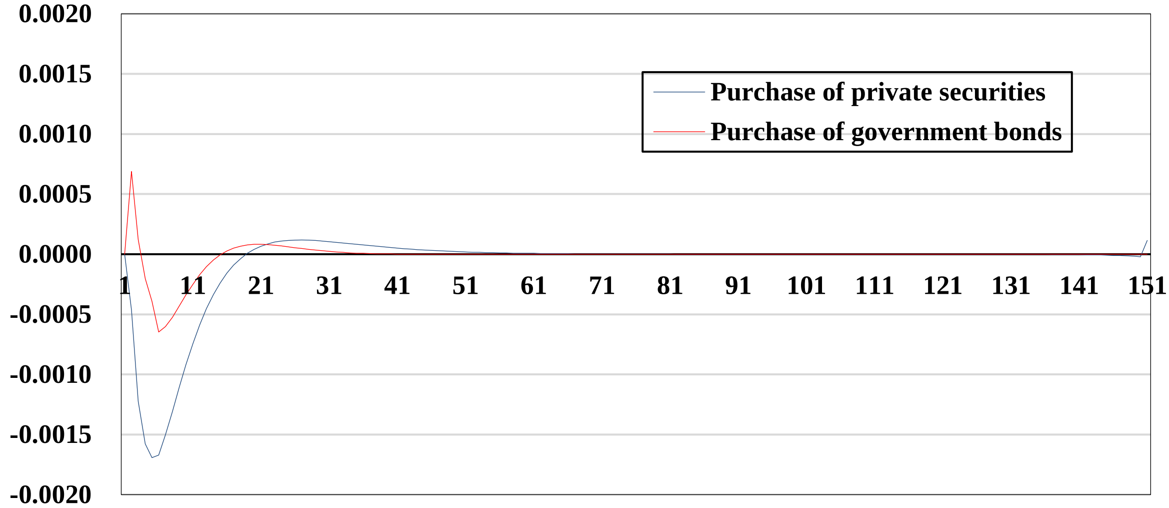
Price of Private Securities



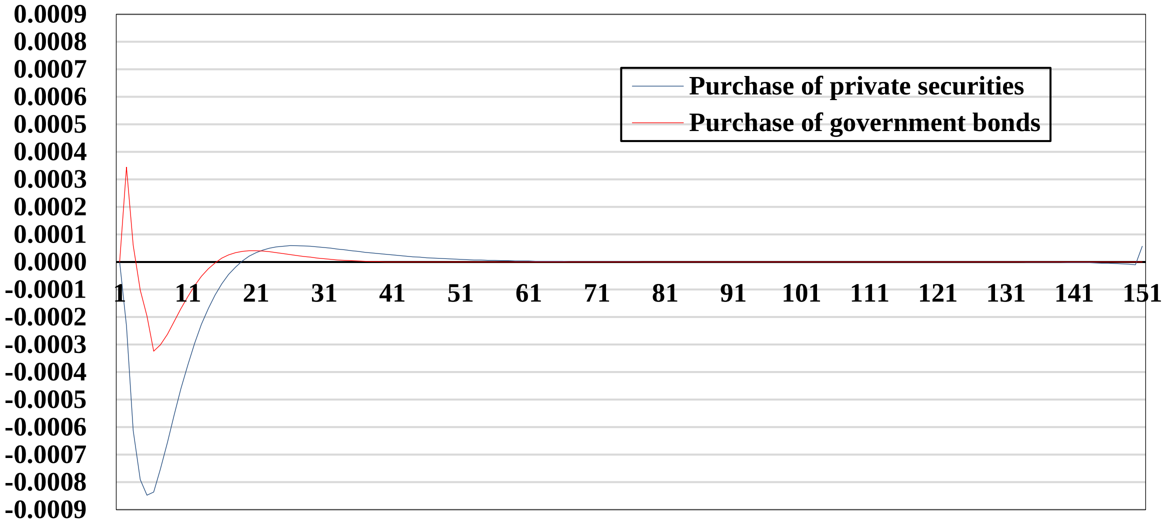
Net Worth (Bank Capital)



Spread for Private Securities $(R_{kt} - R_t)$



Spread for Long-Term Government Securities $(R_{bt} - R_t)$



(Difference in Policy Effectiveness for Large Scale Asset Purchase under ZLB and Non-ZLB)

The effectiveness of purchases of private or long-term government securities vary considerably according on the economic state that adjustment in nominal policy rate is restricted or not, to zero lower bound (ZLB) constraint. In order to understand difference in policy effectiveness for large scale asset purchase policy under a zero lower bound or non-zero lower bound, the policy rate is artificially manipulated in the model referring to two scenarios. In the first scenario, the short-term policy rate is fixed for first four quarters in order to build a policy environment which is similar to zero lower bound restriction. Meanwhile, the policy rate is allowed to be flexibly adjusted following the traditional Taylor rule in the second scenario.

Asset purchase policy is more effective when facing zero lower bound for some periods than when short-term policy rate is adjusted immediately in response to large scale asset purchase shock. When the Central Bank maneuvers its nominal policy rate immediately according to Taylor rule shortly after fulfillment in large scale asset purchase program, such policy effectiveness of asset purchase is shrunk compared to the case of fixed policy rate, regardless of what types of assets are purchased. From this perspective, figure (6.4) and (6.5) indicate that the policy effectiveness by large scale asset purchase can be larger when the policy rate is not altered instantaneously in response to the asset purchase, in both cases of purchasing private securities or long-term government securities.

In sum, this finding has implication that the intermediation through the Central Bank in private or long-term government securities markets is more effective when the policy is conducted under the fixed nominal policy rate for some terms. It is because the effect of asset purchase cannot be offset by the instantaneous change of short-term policy rate when the policy rate is restricted at zero lower bound. Meanwhile, if the policy is not restricted at the zero lower bound, the effectiveness of asset purchase can be reduced because of the immediate adjustment of the policy rate.

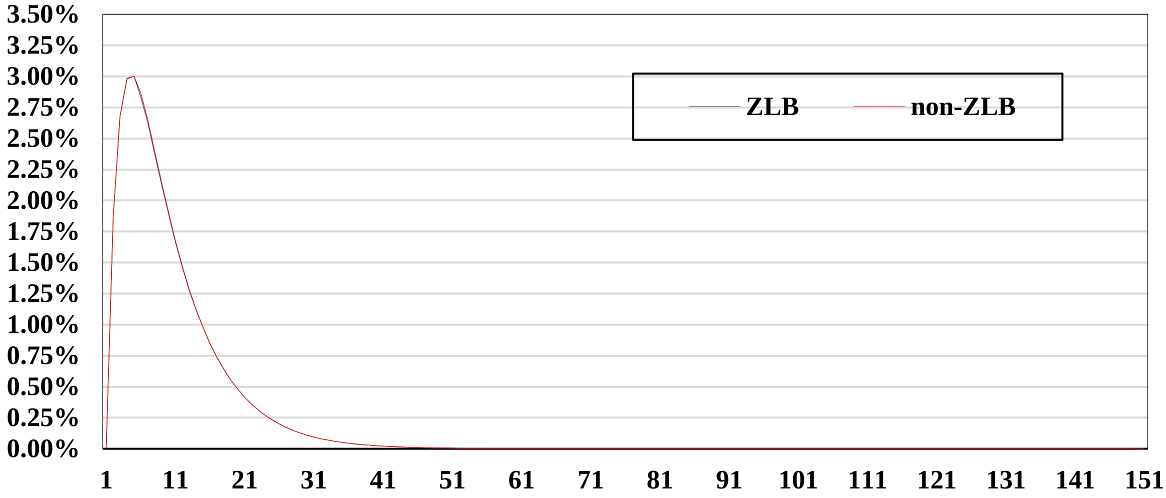
(Difference in Policy Effectiveness for Large Scale Asset Purchase under Household Segmentation)

In this part, it is postulated that households cannot hold long-term private or government securities. This is different from the previous assumption that household can hold financial assets. According to the results of simulations, the policy effectiveness of asset purchase becomes weaker when it is postulated that the household cannot maintain any financial assets including long-term private securities or government securities. The increases in output and inflation caused by asset purchase are weaker when assuming the financial asset segmentation of household in long-term private securities or government securities, compared to possible state of the household's financial asset holding. Figure (6.6) and (6.7) demonstrate this difference.

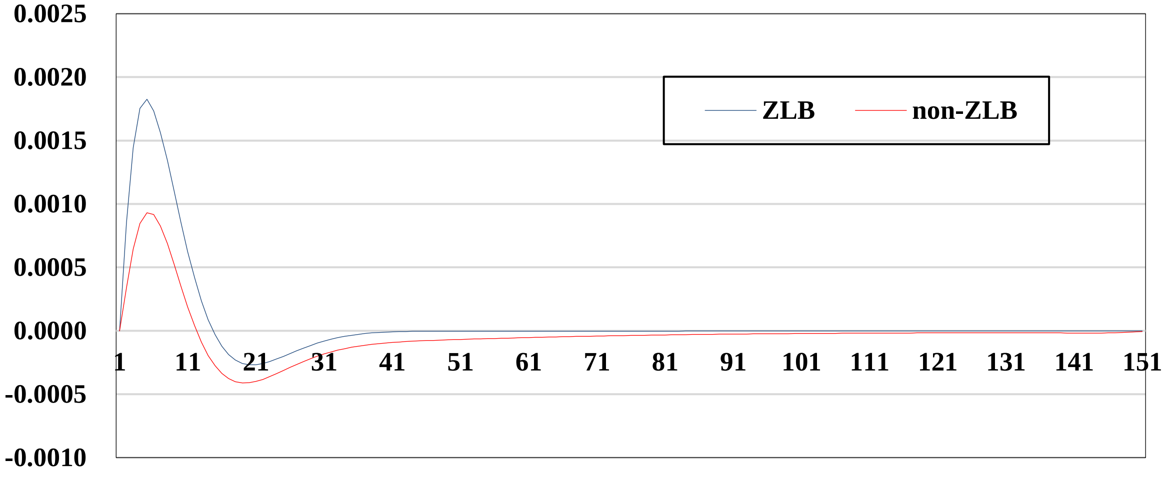
This reflects that under household's financial asset segmentation because the pool of actively traded securities in the securities market decreases, the portion of asset purchase by the Central Bank can be enlarged. As a result of that, the effectiveness of asset purchase by the Central Bank can be also strengthened.

Figure 6.4: Difference in Policy Effectiveness for Long-Term Government Securities under ZLB and non-ZLB

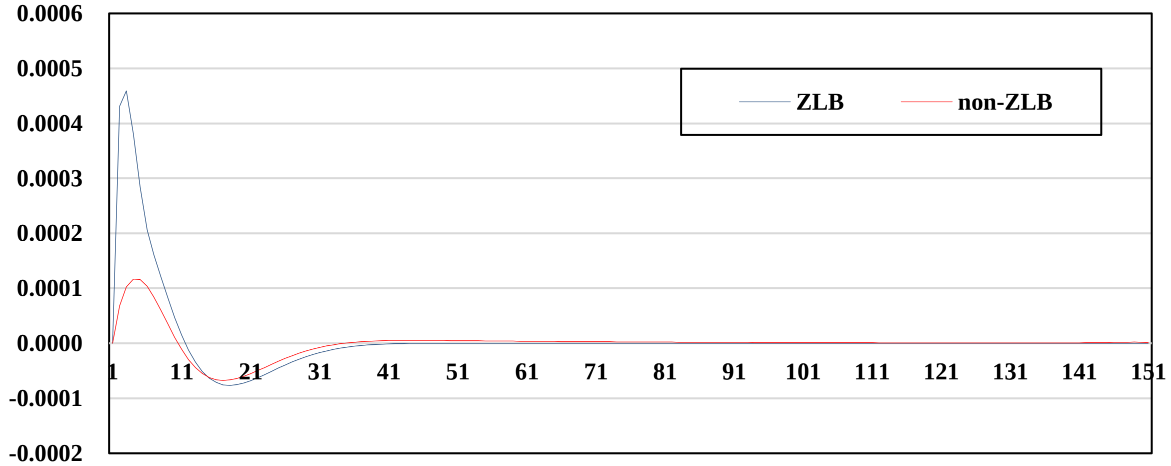
Share of Purchase per GDP



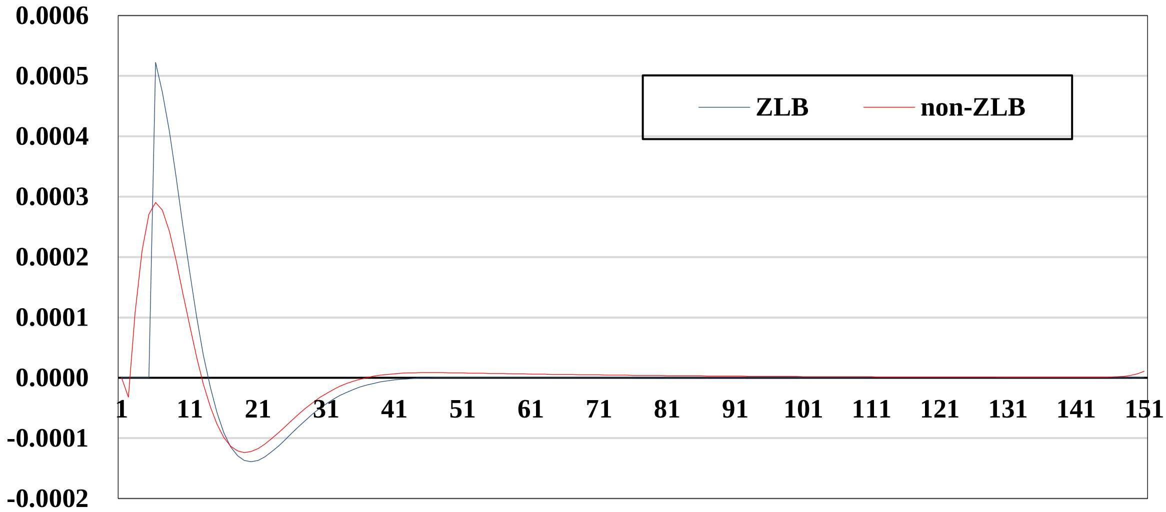
Output



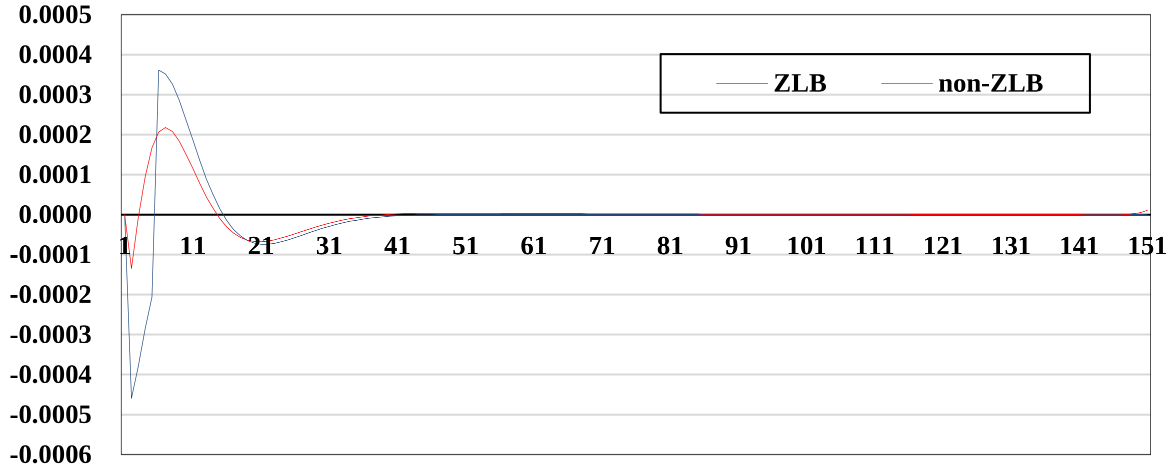
Inflation



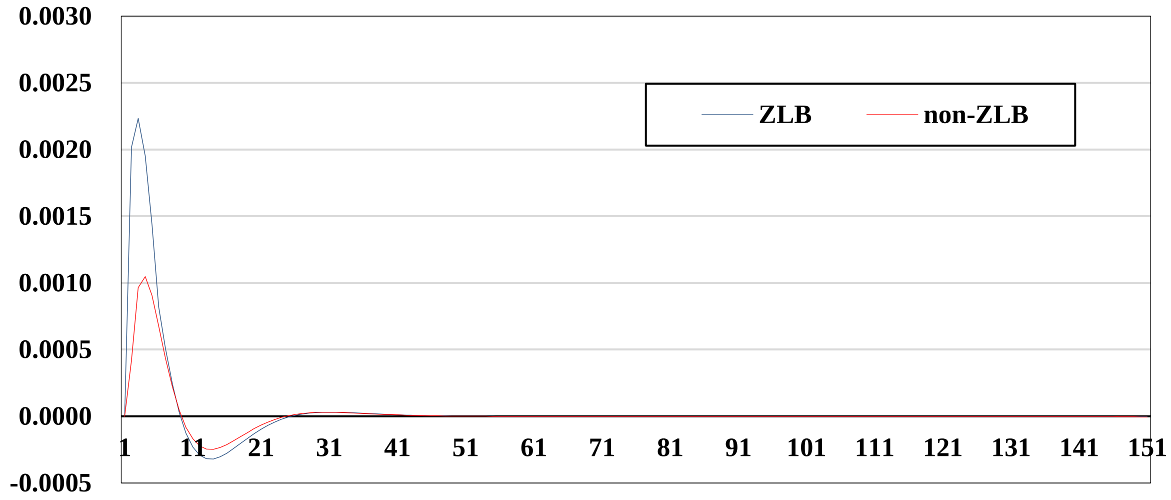
Nominal Policy Rate



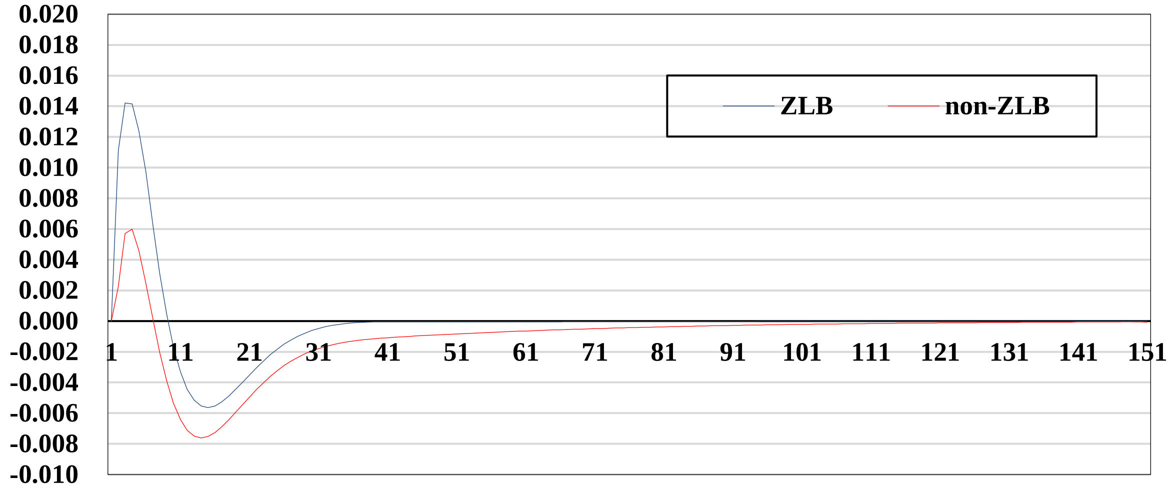
Deposit Rate



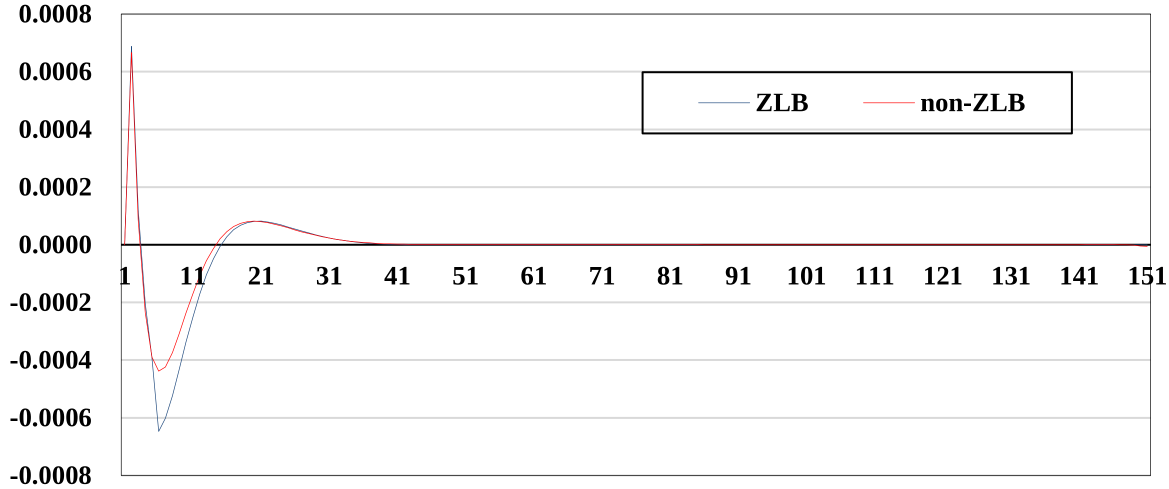
Price of Private Securities



Net Worth (Bank Capital)



Spread for Private Securities $(R_{kt} - R_t)$



Spread for Long-Term Government Securities $(R_{bt} - R_t)$

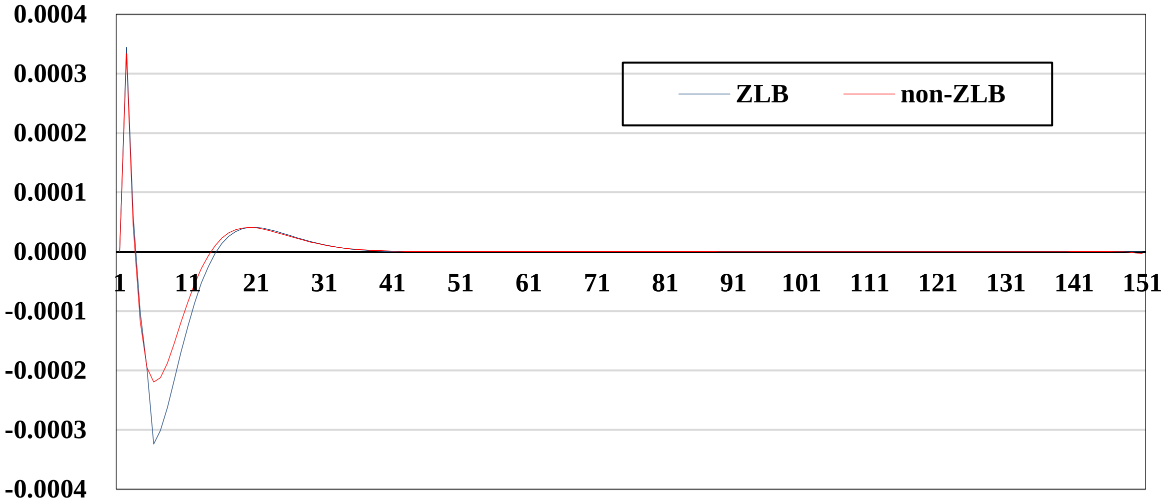
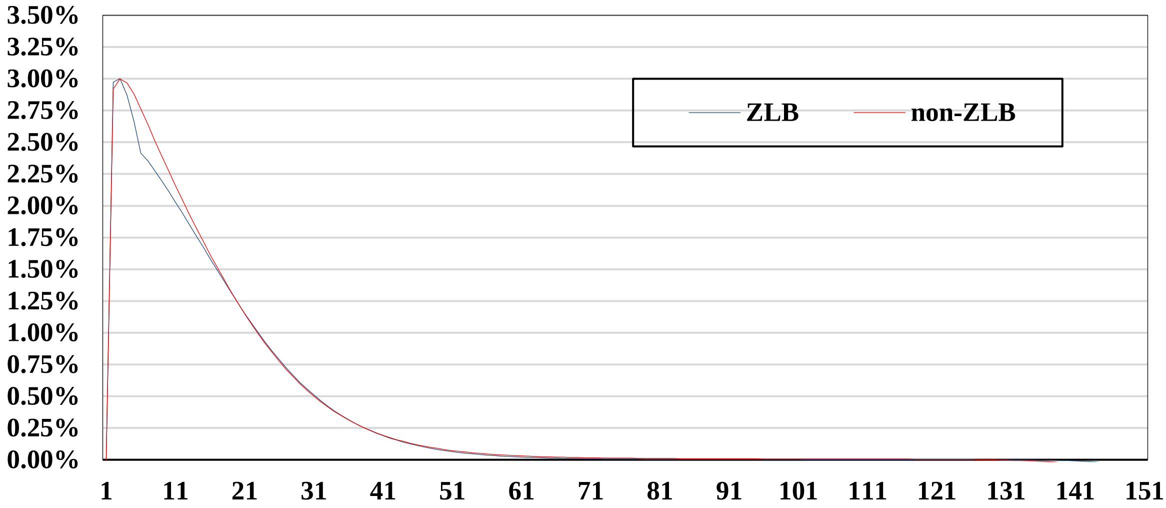
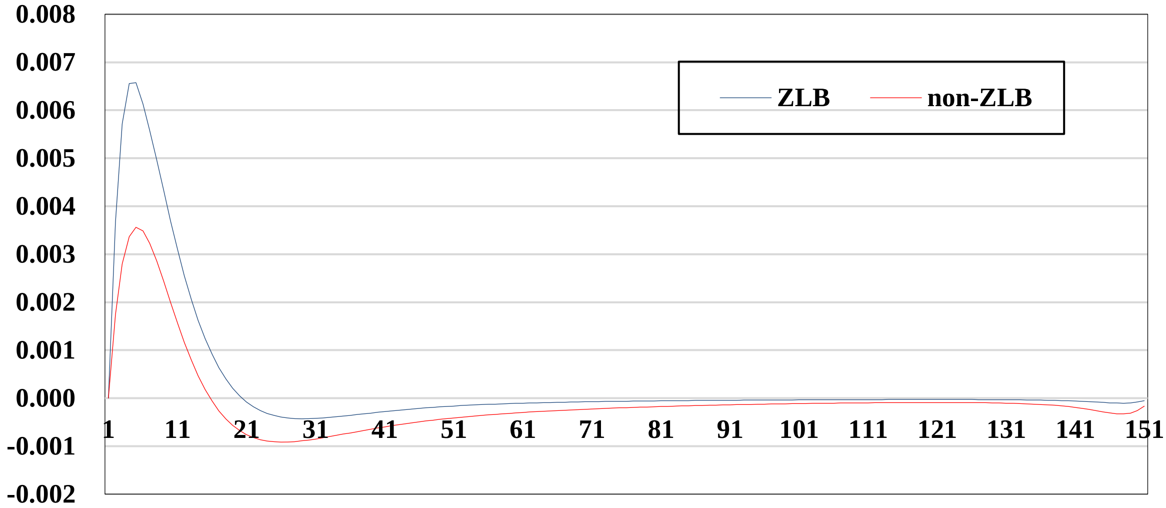


Figure 6.5: Difference in Policy Effectiveness for Private Securities under ZLB and non-ZLB

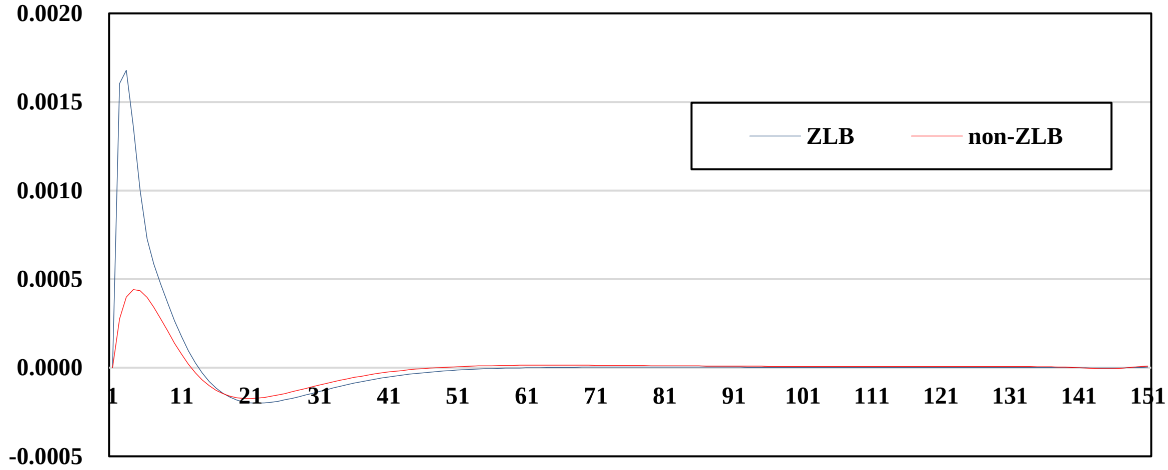
Share of Purchase per GDP



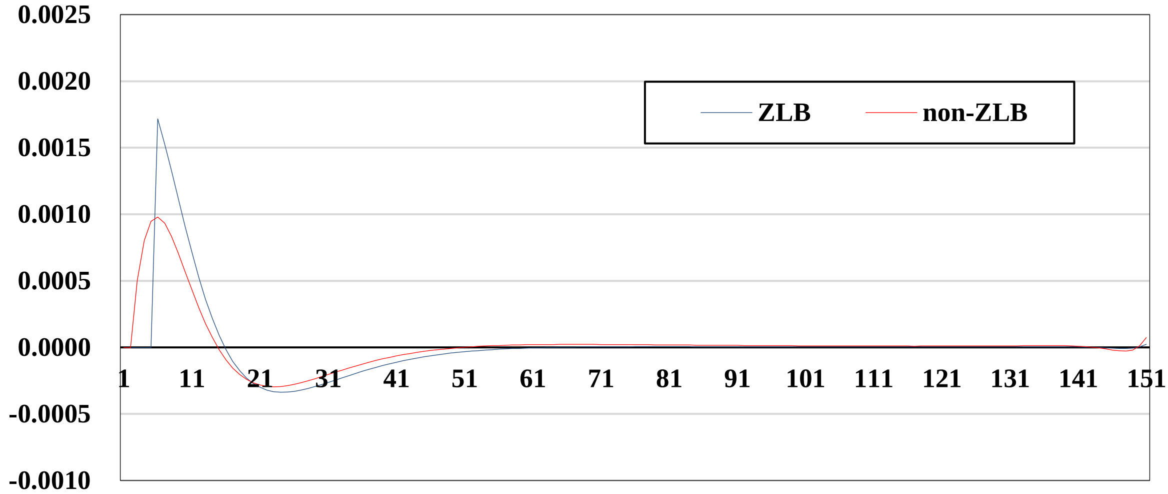
Output



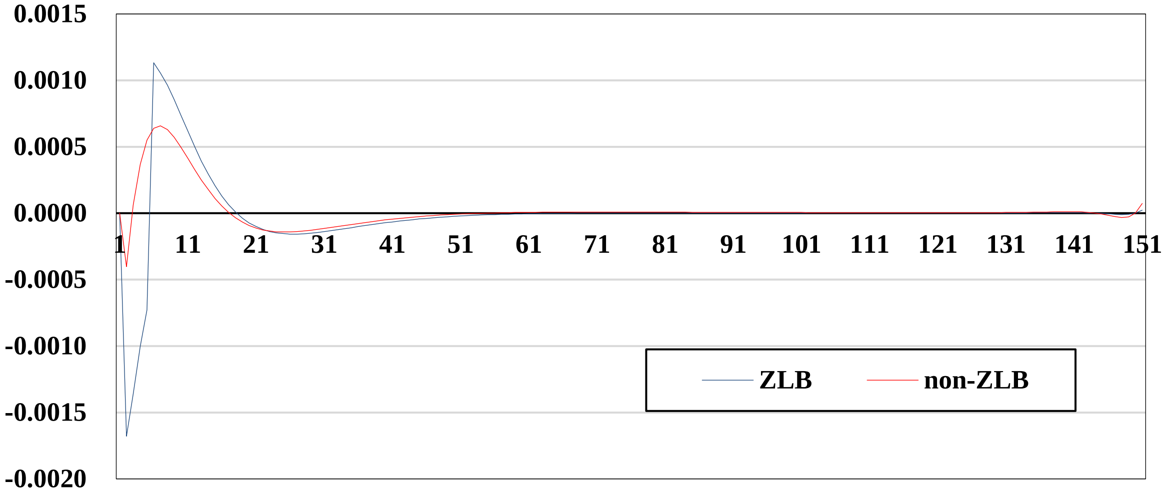
Inflation



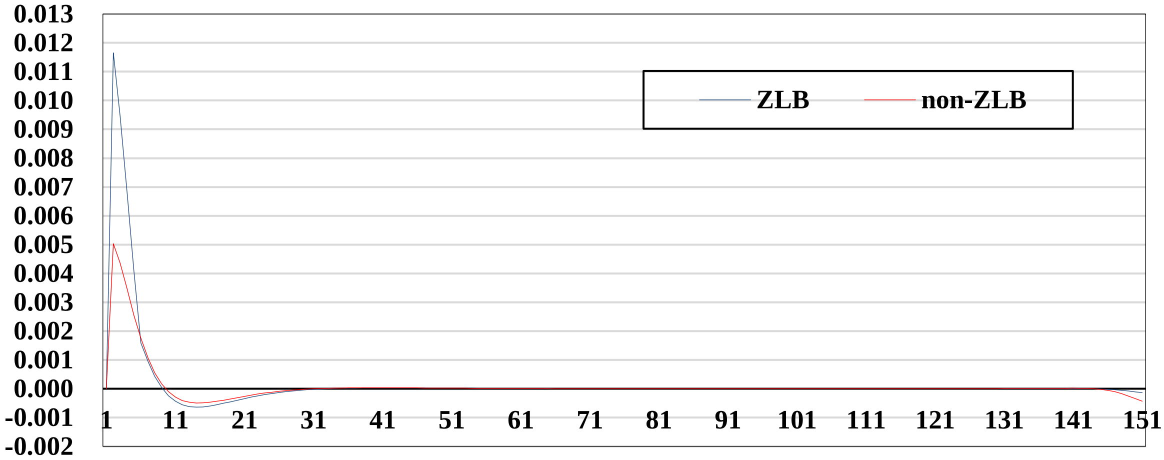
Nominal Policy Rate



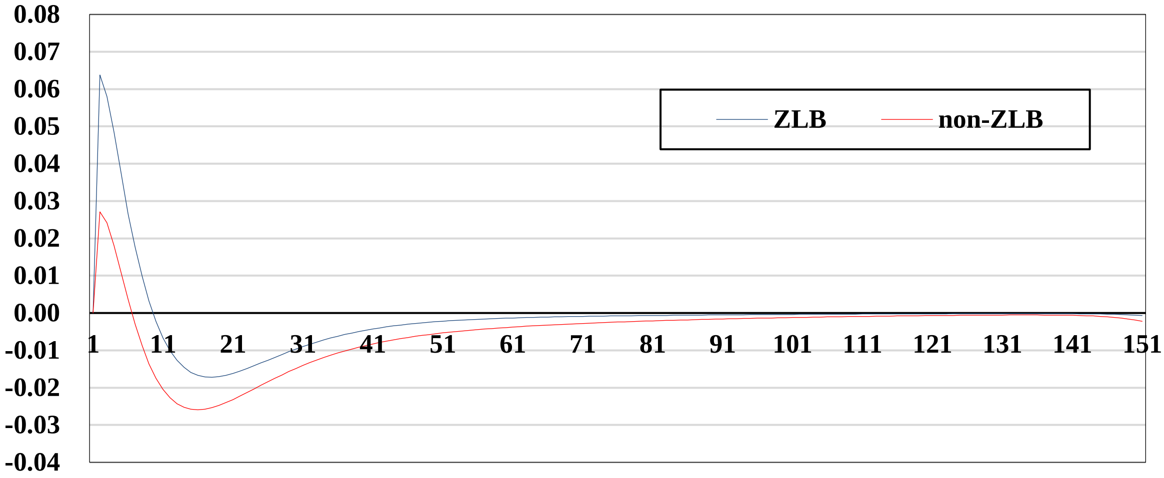
Deposit Rate



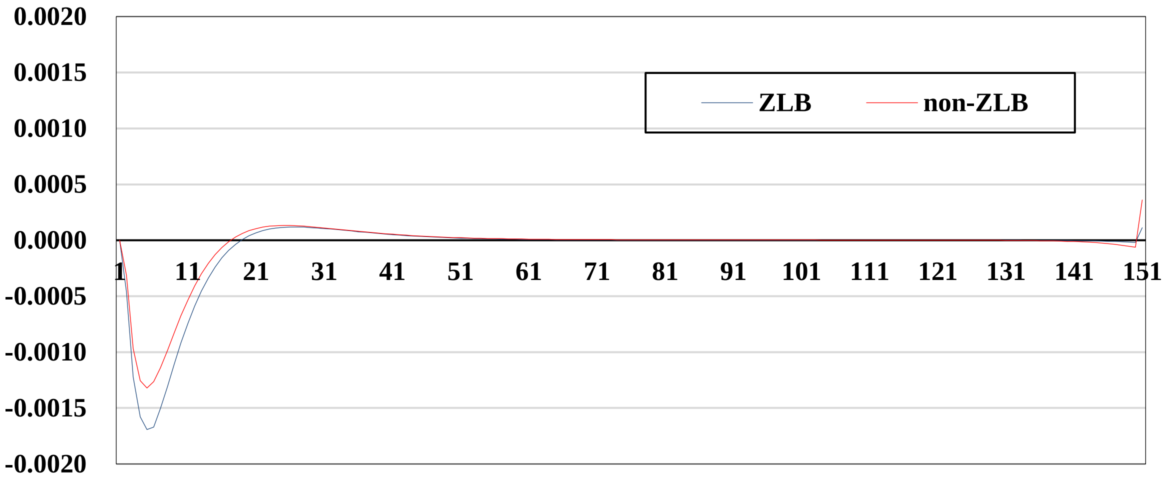
Price of Private Securities



Net Worth (Bank Capital)



Spread for Private Securities $(R_{kt} - R_t)$



Spread for Long-Term Government Securities $(R_{bt} - R_t)$

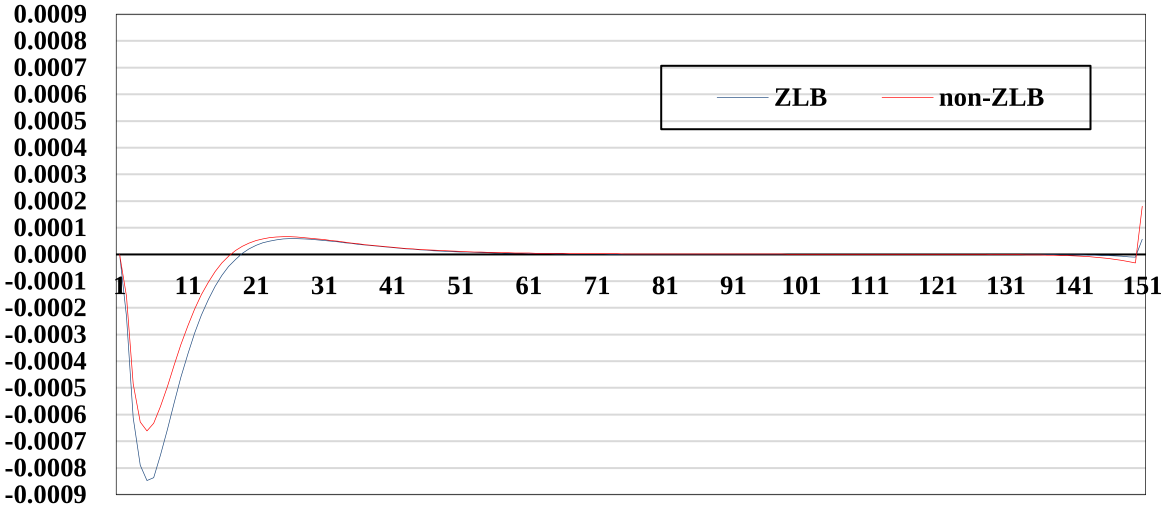
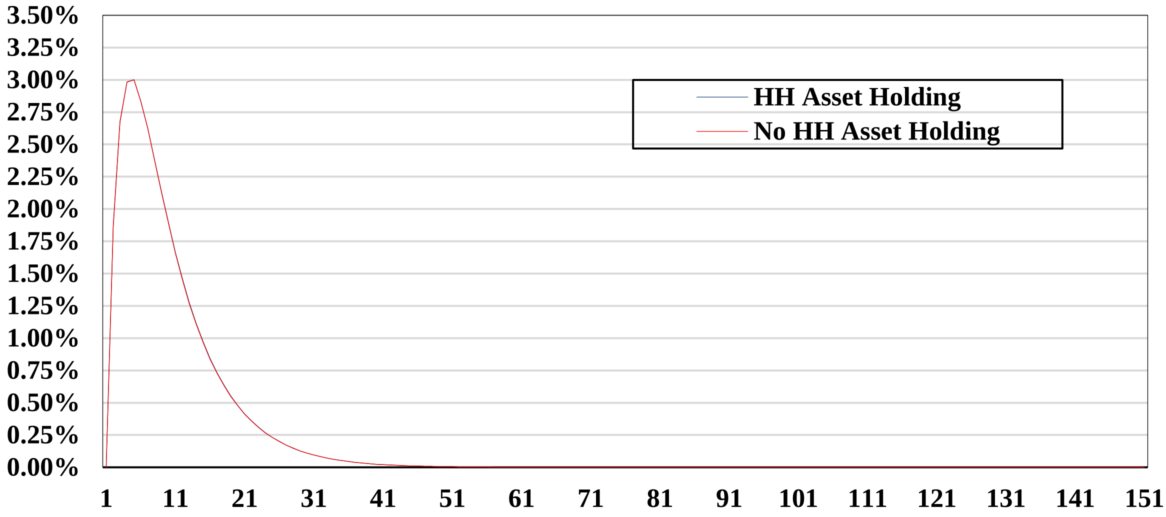
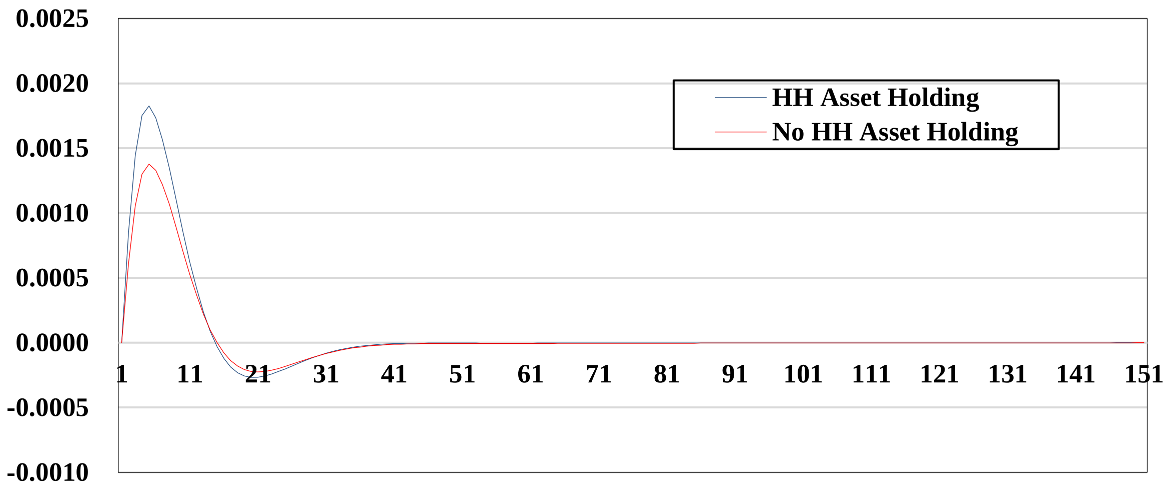


Figure 6.6: Difference in Policy Effectiveness for Long-Term Government Securities under Household Segmentation

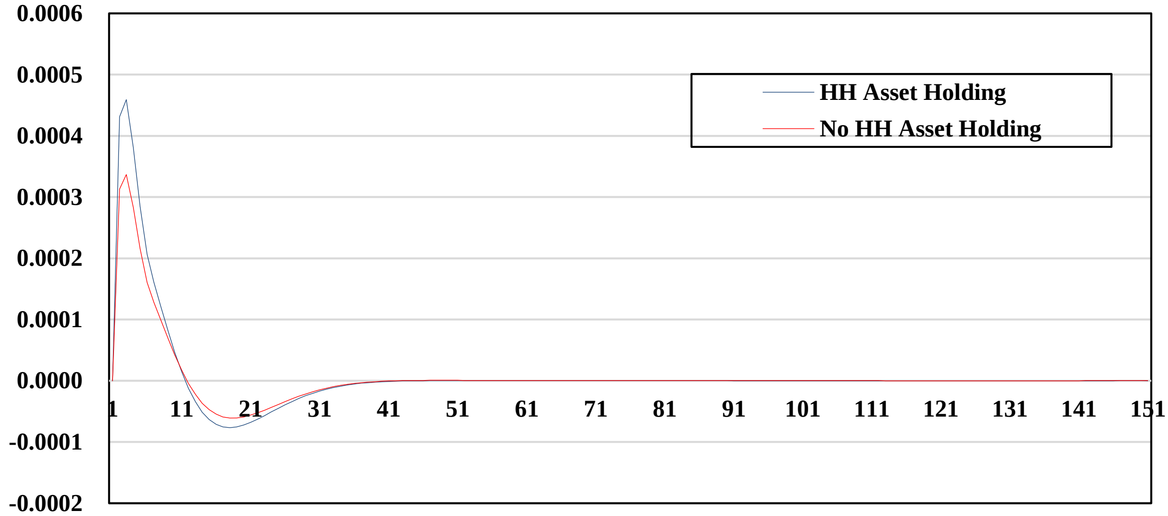
Share of Purchase per GDP



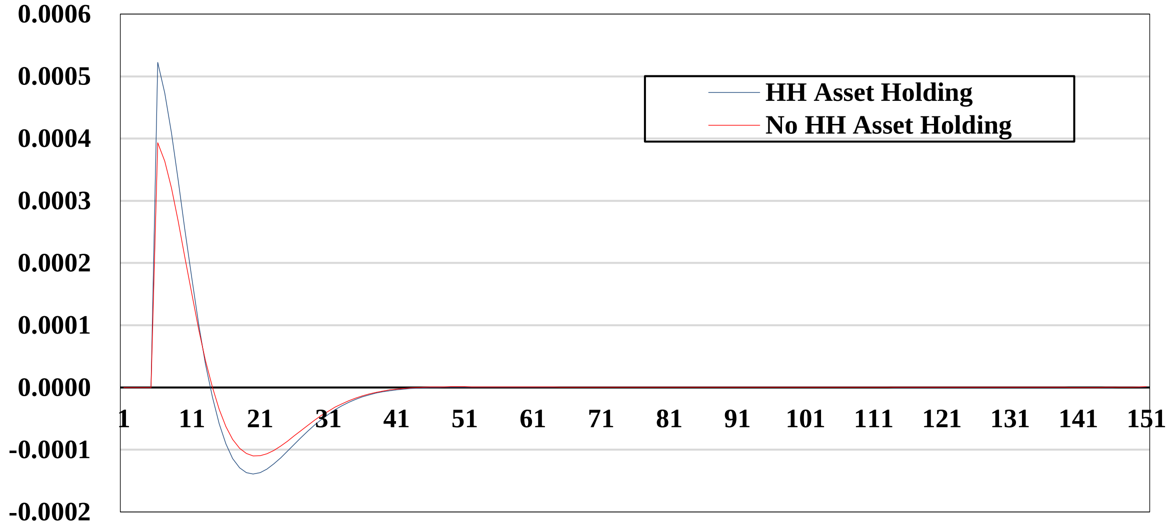
Output



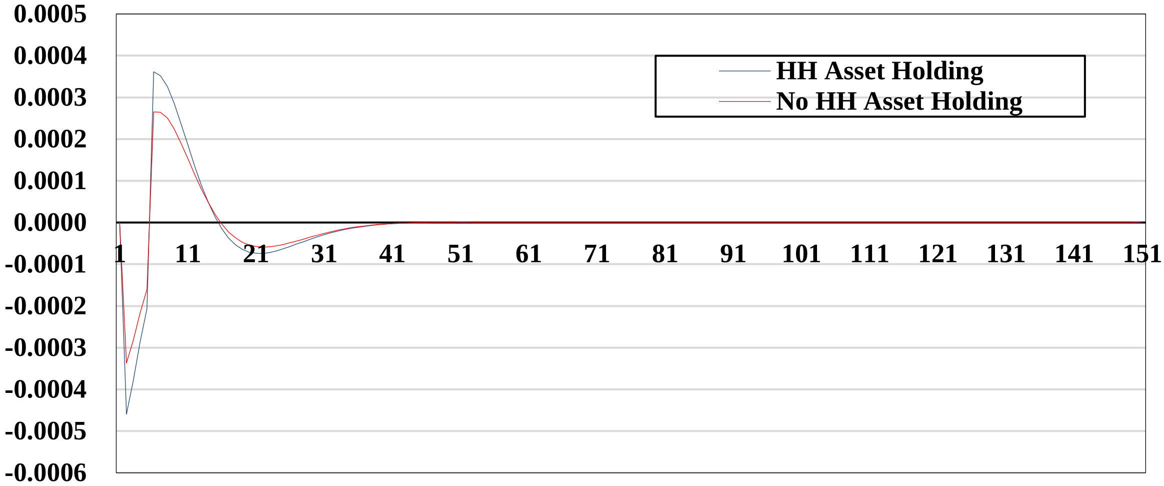
Inflation



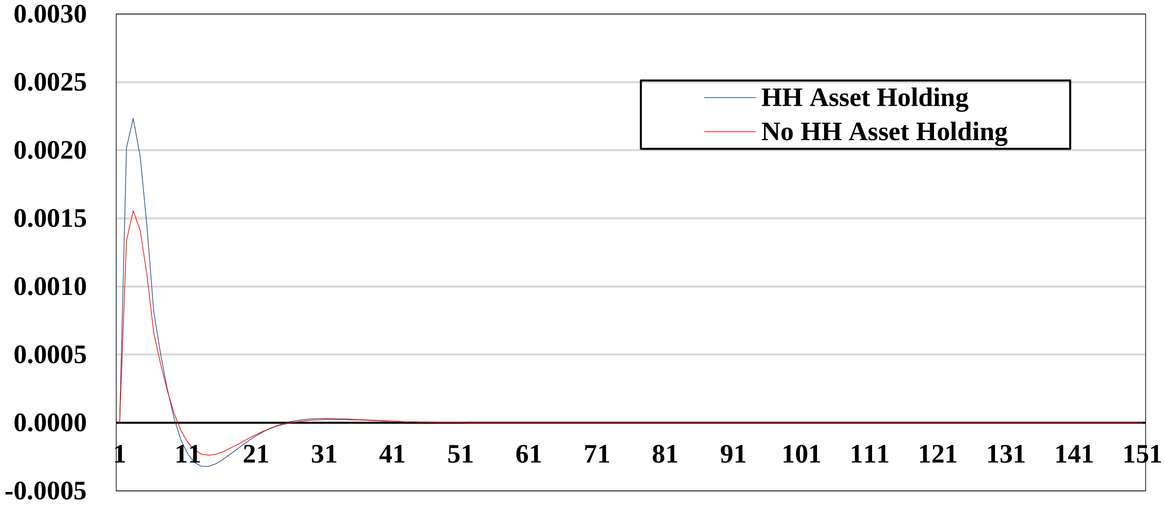
Nominal Policy Rate



Deposit Rate

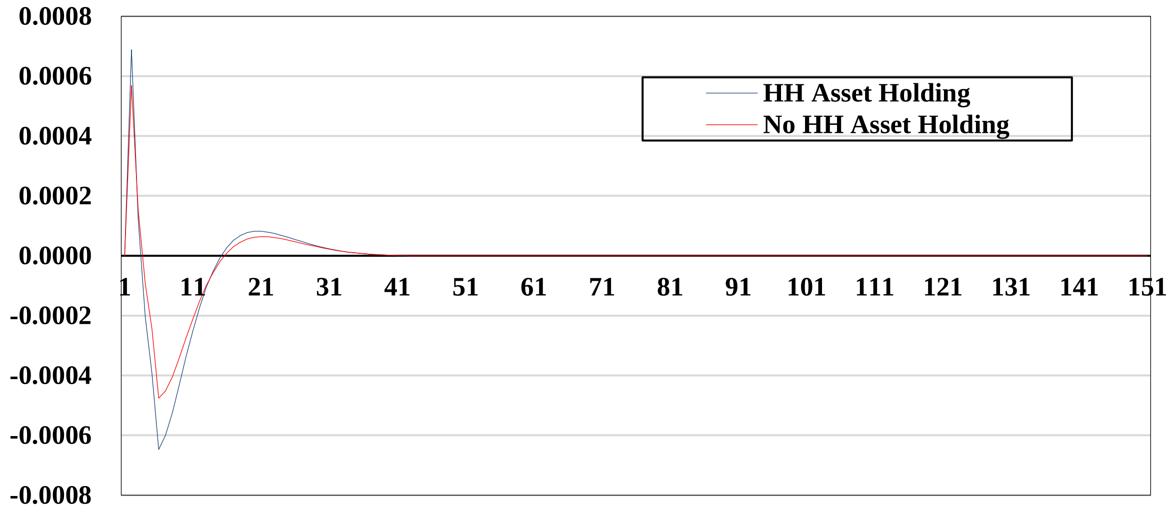


Price of Private Securities



Net Worth (Bank Capital)

Spread for Private Securities $(R_{kt} - R_t)$



Spread for Long-Term Government Securities $(R_{bt} - R_t)$

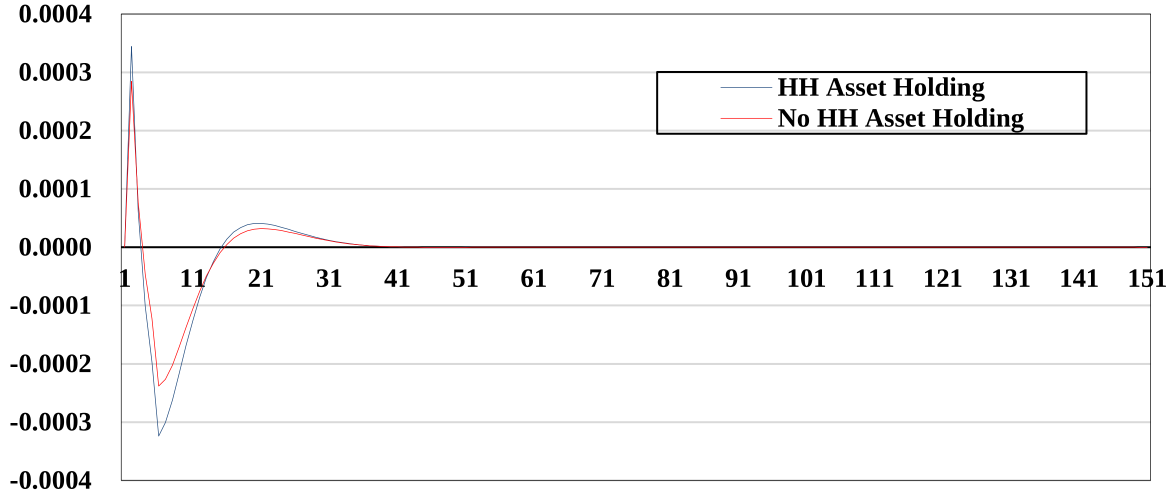
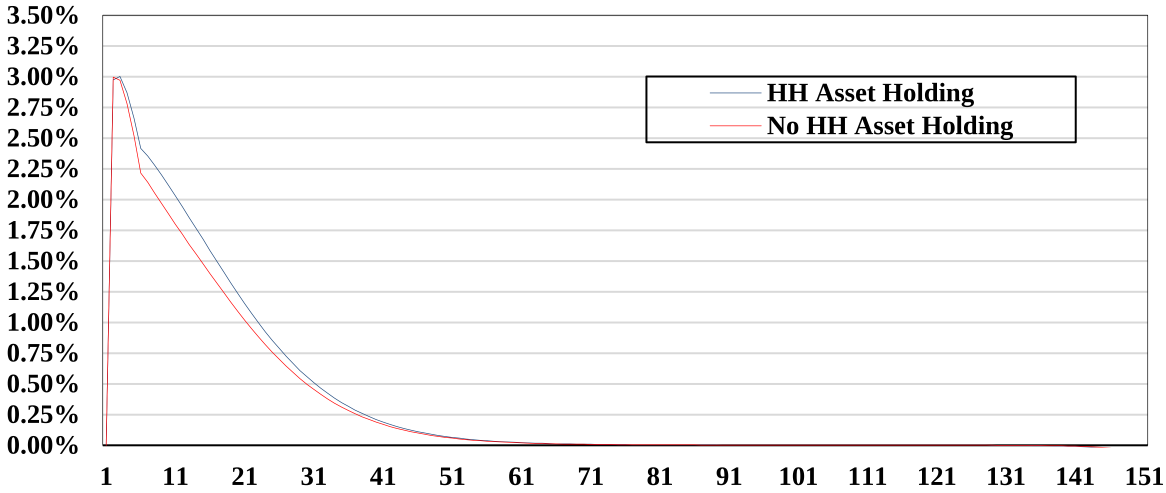
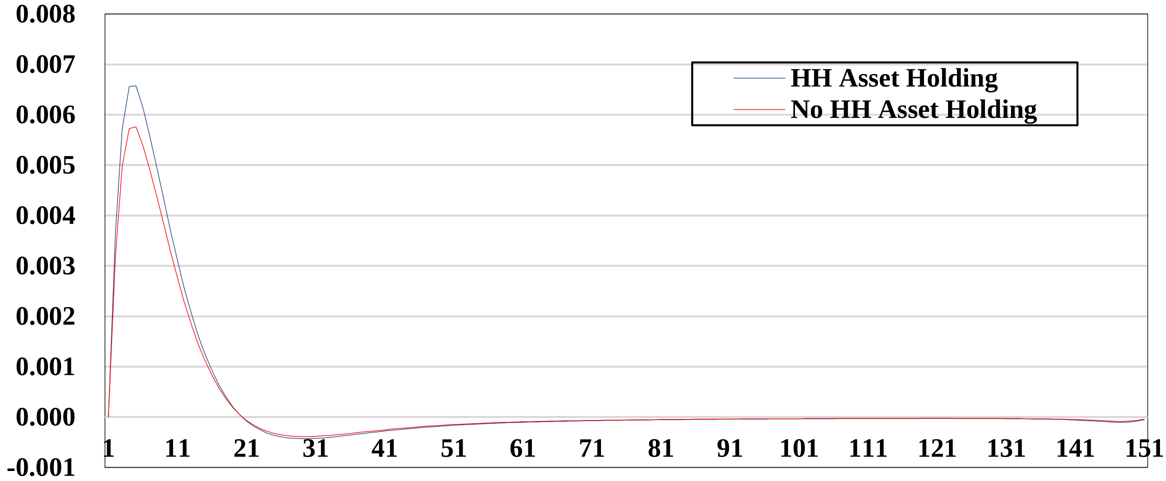


Figure 6.7: Difference in Policy Effectiveness for Private Securities under Household Segmentation

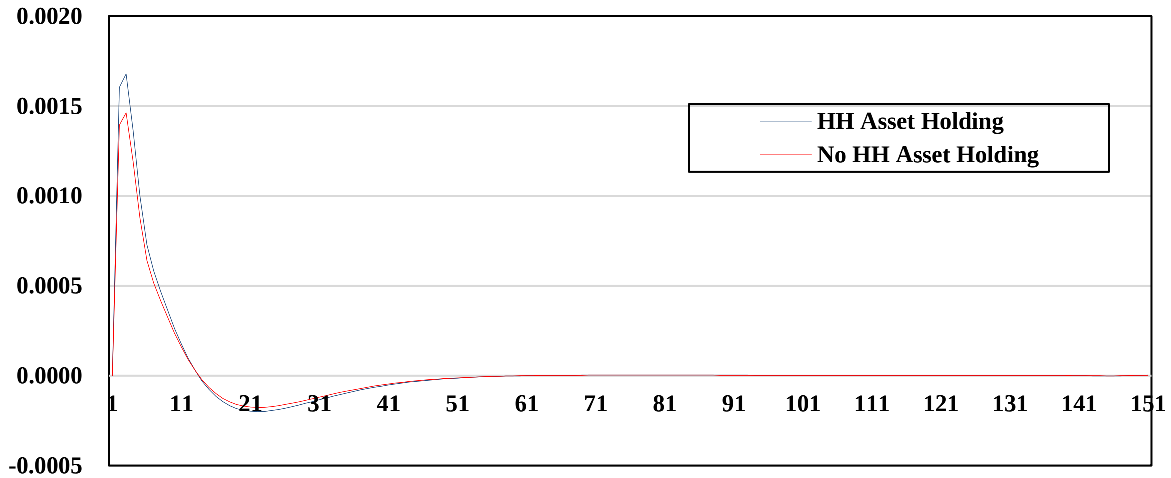
Share of Purchase per GDP



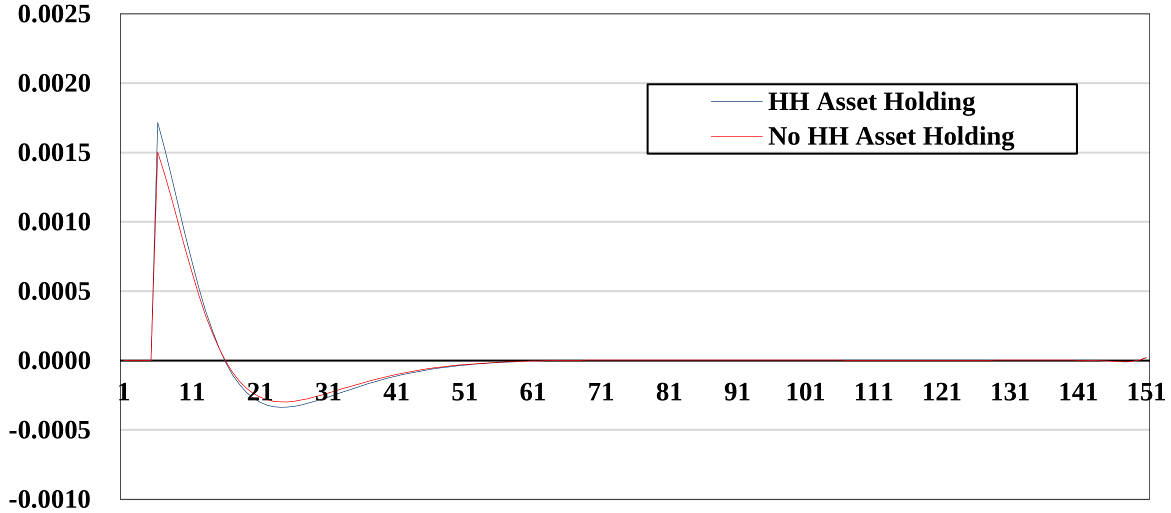
Output



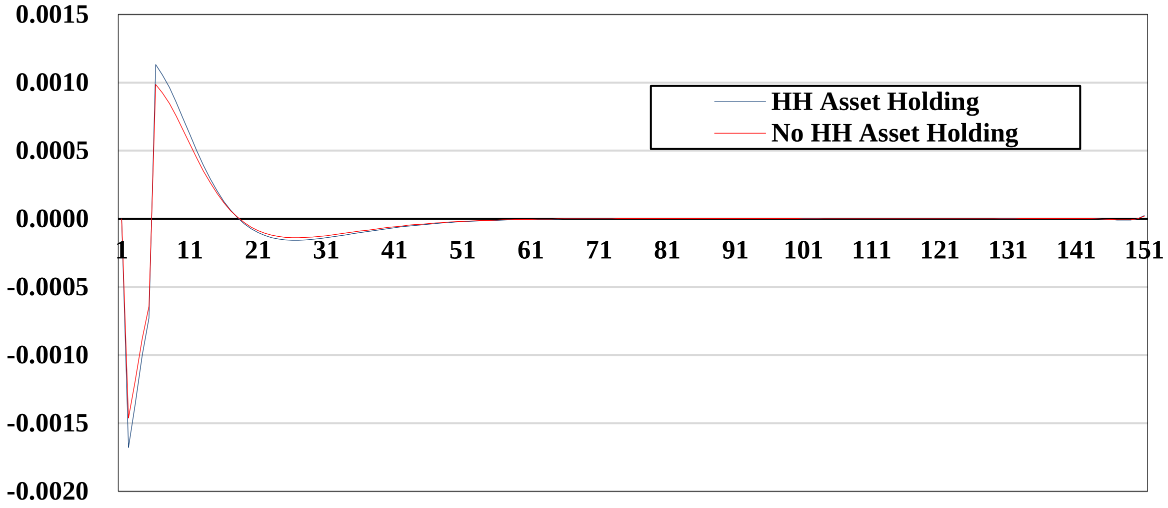
Inflation



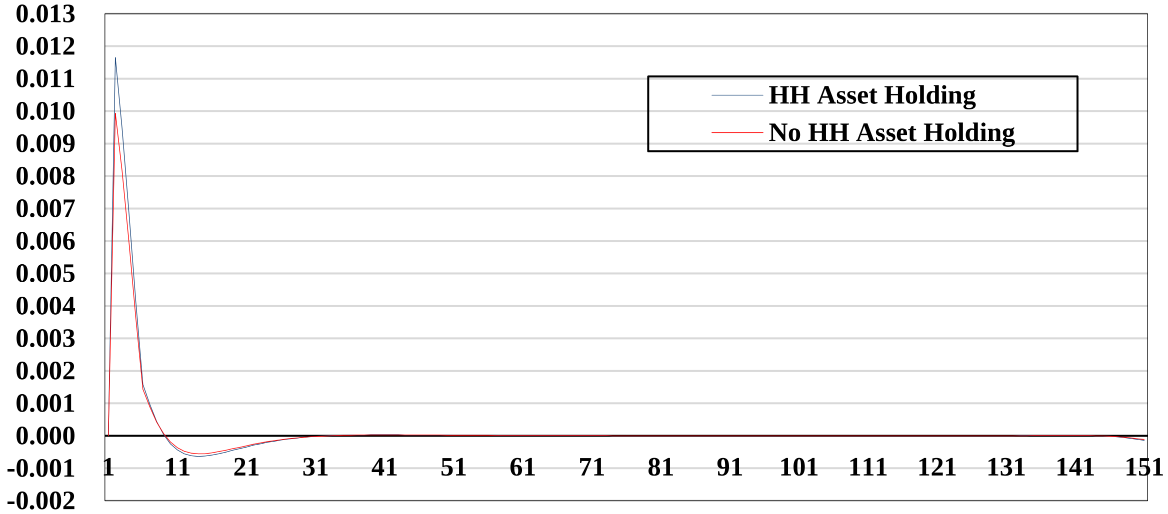
Nominal Policy Rate



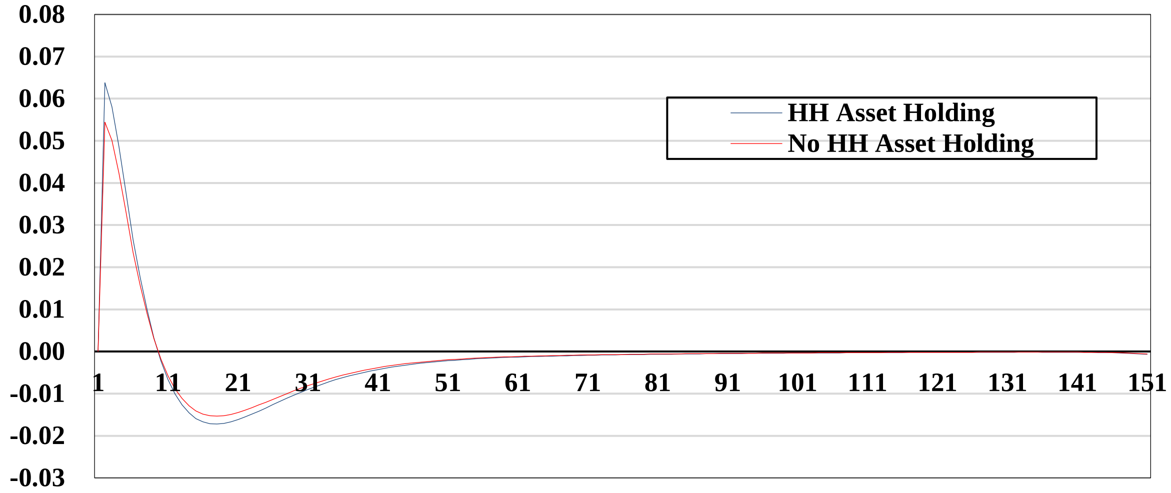
Deposit Rate



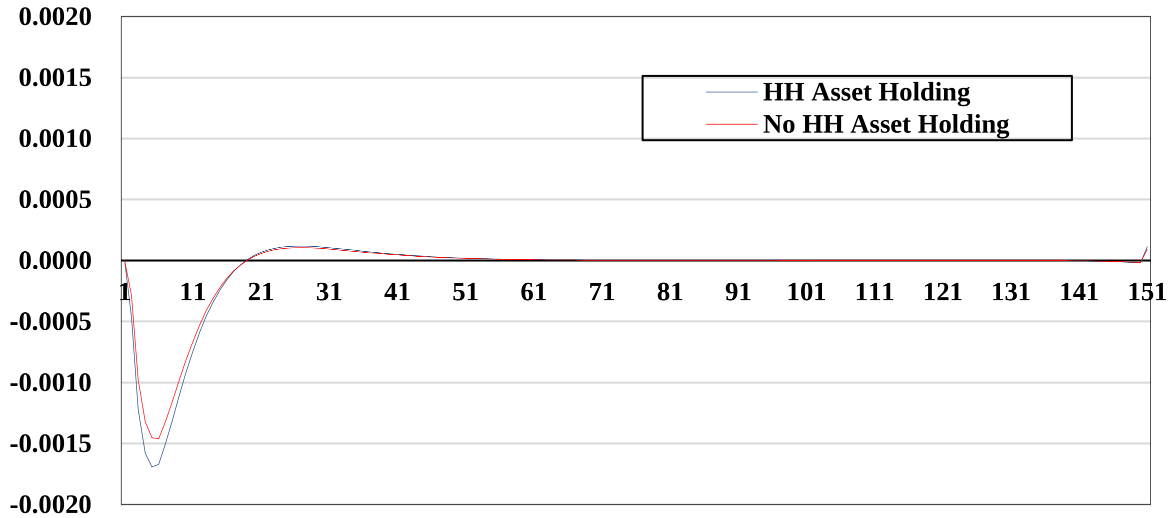
Price of Private Securities



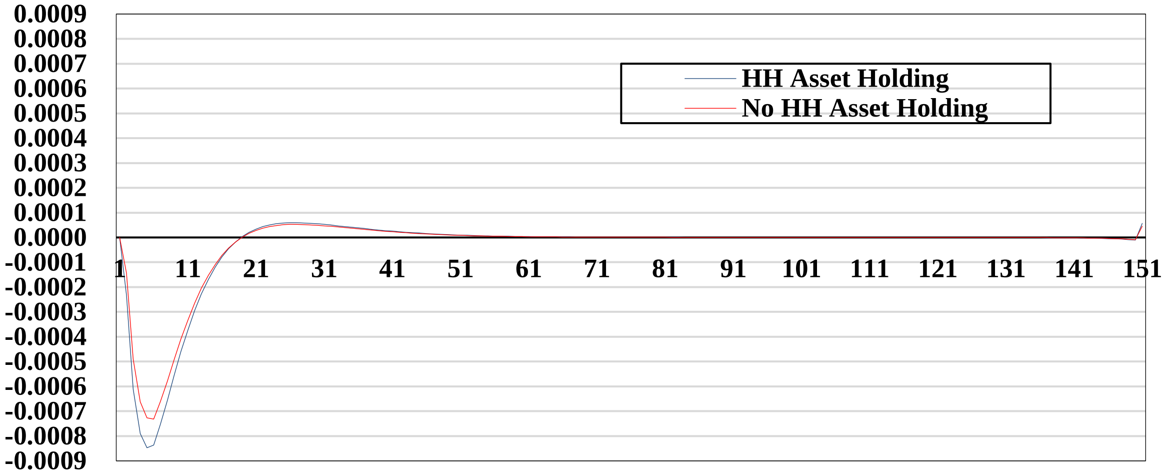
Net Worth (Bank Capital)



Spread for Private Securities $(R_{kt} - R_t)$



Spread for Long-Term Government Securities $(R_{bt} - R_t)$



6.3 Conclusion

In this chapter, theoretical differences in policy effectiveness are analyzed in term of three perspectives applying Gertler and Karadi (2013) typed New-Keynesian DSGE model into Korean economy. Such three perspectives are the differences of policy effectiveness which occur between purchasing private securities and long-term government securities, between under zero lower bound and non-zero lower bound, and between household's asset segmentation and non-asset segmentation.

First, according to policy simulations, it proves purchase of private securities can be more successful than purchase of long-term government securities in terms of stabilizing financial market distress and boosting real activities such as investment and output. In other words, when it is postulated that intervention is conducted in the same degree[18], purchasing private securities including MBS, corporate bonds, commercial papers, etc. can be more effective in boosting real activities and inflation than purchasing similar degree of long-term government securities.

Second, it also turns out that the policy effectiveness for large scale asset purchase can be considerably different according to whether the economic and financial environment is restricted by zero lower bound (ZLB) constraint or not. According to the result of policy experiment, it seems that such large scale asset purchase can be more effective when the Central Bank faces the zero lower bound constraint for some periods than when the short-term policy rate can be adjusted immediately in reaction to large scale asset purchase shock. Specifically, if the Central Bank can adjust its nominal policy rate immediately, for instance following typical Taylor rule, with implementation of large asset purchase program, the intensity of policy effectiveness in such large scale asset purchase program can be offset by flexible adjustment of interest rate.

Third, the policy effectiveness of large scale asset purchase can also become weaker when it is postulated that household cannot keep any financial assets directly such as long-term private or government securities. Namely, it demonstrates that the increases in output and inflation through large scale asset purchase by the Central Bank become weaker when assuming households' financial assets segmentation in regard to long-term private or government securities.

[18] The intensity of intervention is determined as 3% of annual GDP of Korea.

Table 6.2: The Model Summary

Economic Agents	Equation
1. Households	
Stochastic discount factor	$\Lambda_{t\,t+1} = \frac{\varrho_{t+1}}{\varrho_t}$
Euler equation	$E_t \beta \Lambda_{t\,t+1} R_{\,t+1} = 1$
Labor supply	$\varrho_t W_t = \chi L_t^{\varphi}$
Marginal utility of consumption	$\varrho_t = \frac{1}{(C_t - \mu C_{t-1})} - \beta \mu E_t \frac{1}{(C_{t+1} - \mu C_t)}$
2. Banks	
Real rate of return on private security	$R_{k\,t+1} = \frac{[Z_{t+1} + (1-\delta) Q_{t+1}]}{Q_t} \xi_{t+1}$
Real rate of return on long-term government security	$R_{b\,t+1} = \frac{\frac{1}{P_t} + q_{t+1}}{q_t}$
Excess value of loans over deposits	$\nu_{1t} = E_t \Lambda_{t\,t+1}(R_{kt+1} - R_{t+1})$
Excess value of holding long-term government securitis over deposits	$\nu_{2t} = E_t \Lambda_{t\,t+1}(R_{bt+1} - R_{t+1})$
Leverage	$\phi_t = \frac{\eta_t}{\lambda - \nu_{1\,t}}$
Net worth evolution	$N_t = N_{et} + N_{nt}$
Net worth of existing bankers	$N_{et} = \theta[(R_{kt} - R_t) \frac{Q_{t-1} S_{t-1}}{N_{t-1}} + (R_{bt} - R_t) \frac{q_{t-1} B_{t-1}}{N_{t-1}} + R_t] N_{t-1}$
Net worth of new bankers	$N_{nt} = \omega Q_t S_{t-1}$
3.Intermediate Good Producing Firms	
Production function	$Y_{mt} = A_t (Z_t \xi_t K_t)^{\alpha} L_t^{\,1-\alpha}$
Labor demand	$P_{mt}(1-\alpha) \frac{Y_{mt}}{L_t} = W_t$
Capacity utilization	$P_{mt} \alpha \frac{Y_{mt}}{Z_t} = \delta'(Z_t) \xi_t K_t = b Z_t^{\zeta} \xi_t K_t$
Depreciation rate	$\delta(Z_t) = \delta_c + \frac{b}{1+\zeta} Z_t^{1+\zeta}$
Return on capital	$R_{k\,t+1} = \frac{[P_{mt+1} \alpha \frac{Y_{m\,t+1}}{\xi_{t+1} K_{t+1}} + Q_{t+1} - \delta(Z_{t+1})] \xi_{t+1}}{Q_t}$
4. Capital-Producing Firms	
Net investment	$I_{nt} \equiv I_t - \delta(Z_t)\, \xi_t K_t$
Optimal net investment decision	$Q_t = 1 + \Xi_t + \frac{I_{nt} + I_{SS}}{I_{nt-1} + I_{SS}} \Xi_t{}' - E_t \beta \Lambda_{t,t+1} (\frac{I_{nt+1} + I_{SS}}{I_{nt} + I_{SS}})^2 \Xi_{t+1}{}'$
Investment adjustment cost	$\Xi_t = \frac{\eta_i}{2} (\frac{I_{nt} + I_{SS}}{I_{nt-1} + I_{SS}} - 1)^2$
Capital accumulation	$K_{t+1} = \xi_t K_t + I_{nt}$
5. Retail Firms	
Final goods production	$Y_t = D_t Y_{mt}$
Price dispersion	$D_t = \gamma D_{t-1} \Pi_{t-1}^{-\gamma_p \varepsilon} \Pi_t^{\varepsilon} + (1-\gamma)(\frac{1 - \gamma \Pi_{t-1}^{\gamma_p (1-\gamma)} \Pi_t^{\gamma - 1}}{1-\gamma})^{-\frac{\varepsilon}{1-\gamma}}$
Inflation dynamics	$\Pi_t^{1-\varepsilon} = \gamma \Pi_{t-1}^{\gamma_p (1-\varepsilon)} + (1-\gamma)(\Pi_t^{*})^{\,1-\varepsilon}$
6. Monetary and Credit Policy	
Taylor rule	$i_t = i_{t-1}^{\rho} (\pi_t^{\kappa_\pi} y_t^{\kappa_y})^{1-\rho} exp(\varepsilon_t^i)$
Credit policy for private securities	$S_{gt} = \varpi_{st} S_t$
Credit policy for long-term government securities	$B_{gt} = \varpi_{bt} B_t$

Economic Agents	Equation
7. Household Asset Segmentation	
Demand for private securities	$S_{ht} = S_h + \frac{E_t \Lambda_{t,t+1}(R_{kt+1} - R_{t+1})}{\kappa}$
Demand for long-term government securities	$B_{ht} = B_h + \frac{E_t \Lambda_{t,t+1}(R_{bt+1} - R_{t+1})}{\kappa}$
8. Other Equations	
Economy resource constraint	$Y_t = C_t + I_t + \Xi(\frac{I_t}{I_{t-1}}) I_t + G + \tau_s Q_{t-1} S_{gt-1} + \tau_b q_{t-1} B_{gt-1}$
Fisher equation	$1 + i_t = R_{t+1} \frac{E_t P_{t+1}}{P_t}$

Chapter 7. The Complementarity between Conventional and Unconventional Monetary Policy

7.1 The Model

7.1.1 Overview

We investigate the connection between conventional and unconventional monetary policy in Korea. Since the Great Recession occurred in the late 2008, many Central Banks in small open emerging economies have not been able to lower their policy rates to the zero lower bound because they were restricted by issues such as the risk of capital outflow and risks to domestic financial stability occurring from soaring household credit. However, with the continuation of the economic recession for a long time, the issue of whether it is possible to conduct non-traditional monetary policy such as a large scale asset purchase alongside conventional monetary policy has started to become more prominent in many emerging economies even where such nominal policy rate has remained above the zero lower bound.

Against this backdrop, in this chapter, we try to find whether unconventional monetary policy like large scale asset purchase can be conducted alongside conventional monetary policy like adjustment of short-term policy rate in Korea. To do this, we employ the model of Ellison and Tischbirek (2013). Ellison and Tischbirek extend canonical New-Keynesian DSGE model including a stylized financial sector and asset purchase by the Central Bank in the context of preferred habitat theory. They find that proper mixture of conventional and unconventional monetary policy can contribute to stabilize inflation and output more effectively.

The model used in this chapter is different from the models used in the previous chapters in terms of a few characteristics. In this model, perfect competition in the banking sector is supposed. Hence, financial frictions are not introduced. Firms do not borrow funds from banks. Furthermore, households do not make deposits in banks and purchase assets. In addition, capital is not considered.

In the model, economy is composed of four agents such as households, firms, banks, and the Central Bank (or a treasury). Price rigidity is also incorporated but it is postulated that wages are fully flexible.

7.1.2 Households

The household utility is separable in consumption and labor. It is described as

$$E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{\mu_t^C}{1-\delta} C_{t+i}^{1-\delta} - \frac{\mu_t^L}{1+\varphi} L_{t+i}^{1+\varphi}\right] \tag{7.1}$$

where $0 < \beta < 1$ and $\delta,\ \varphi > 0$. C_t represents household consumption. L_t is the number of hours worked. μ_t^C and μ_t^L denote exogenous preference shocks which follow an AR(1) process.

Households' consumption is a consumption index defined below. Households choose the composition of consumption in order to minimize their cost. ε_t denotes time-varying constant elasticity of substitution.

$$C_t = \left[\int_0^1 C_t(i)^{\frac{\varepsilon_t - 1}{\varepsilon_t}} di\right]^{\frac{\varepsilon_t}{\varepsilon_t - 1}} \tag{7.2}$$

It is assumed that time-varying substitution elasticity between products follows an AR(1) process.

$$l\,n\left(\frac{\varepsilon_t}{\varepsilon}\right) = \rho_\varepsilon l\,n\left(\frac{\varepsilon_{t-1}}{\varepsilon}\right) + u_t^\varepsilon\,,\ \ u_t^\varepsilon \sim N(0,\ \sigma_\varepsilon^2) \tag{7.3}$$

The household budget constraint is

$$P_t C_t + P_t^S S_{t,t+1} + T_t = W_t L_t + \ S_{t,t-1} + (1 - t_d)(P_t Y_t - W_t L_t) \tag{7.4}$$

where W_t denotes nominal wage, T_t are lump sum taxes paid to government, $S_{t,t+1}$ denotes quantity of a savings instrument, P_t^S is unit price of the savings instrument issued by the commercial banks and purchased by households. $P_t (= \left[\int_0^1 P_t(i)^{1-\varepsilon_t}\, di\right]^{\frac{1}{1-\varepsilon_t}})$ represents the price of composite consumption good. t_d represents tax rate for dividend income, which is given by $P_t Y_t - W_t L_t$.

The first order conditions in regard to consumption and labor supply can be derived as

$$\frac{W_t}{P_t} = \frac{\mu_t^L}{\mu_t^C} L_t^\varphi C_t^\delta \tag{7.5}$$

$$\beta E_t\left[\frac{\mu_{t+1}^C}{\mu_t^C}\left(\frac{C_{t+1}}{C_t}\right)^{-\delta} \frac{P_t}{P_{t+1}}\right]\frac{1}{P_t^S} = 1 \tag{7.6}$$

7.1.3 Banks

Banks are competitive. The representative bank takes nominal deposits from households and issues the savings instrument. It is assumed that the bank determines maturity composition of aggregate savings instrument. To be concrete, the bank determines the amount of deposits which are invested into short- or long-term government bonds, respectively. In this model, following the tradition of the preferred habitat model[19], it is postulated that investors have unique preference for each specific asset with maturities satisfying their preferred investment horizon. Households regard financial assets with different maturities as imperfect substitutes. Meanwhile, financial structure of banks in this model differs from the banks analyzed in chapters 3, 4, 5, and 6 since banks have zero net worth due to perfect competition.

Banks act as financial intermediaries. They purchase short- and long-term government debt and offer a savings instrument to households. This savings instrument combines the features of short- and long-term debt into a composite asset designed for matching the bank's perception for investment horizon preferred by households. Hence, allocation problem which representative bank face can be expressed as

$$\max_{B_{t,t+1},\ Q_{t,t+\tau}} \ V\left(\frac{B_{t,t+1}}{P_t}, \frac{Q_{t,t+\tau}}{P_t}\right) \tag{7.7}$$

subject to the flow budget constraint of the bank

[19] Vayanos and Vila (2009)

$$P_t^S S_{t\,t+1} \;= P_t^B B_{t\,t+1} + P_t^Q Q_{t\,t+\tau} \tag{7.8}$$

where $S_{t\,t+1}$ is the quantity of savings assets created by banks, $B_{t\,t+1}$ denotes the quantity of short-term government securities, and $Q_{t\,t+\tau}$ represents the long-term government securities. P_t^S is the relative price of savings instrument, P_t^B denotes the relative price of short-term government securities, and P_t^Q represents the relative price of long-term government securities.

In order to derive an asset demand schedule, the Generalized Translog (GTL)[20] model is used. This approach is used because it is flexible and gives an analytical solution. However, it is not based on household's utility function.

With the Trans-log, the log of the indirect utility function is expressed as

$$log(V_t^*) = \alpha_o + \sum_m \alpha_1^m \, log\left(\frac{P_t^m}{P_t^S s_{t\,t+1} - P_t^B \Omega^B - P_t^Q \Omega^Q}\right) \tag{7.9}$$

$$+ \frac{1}{2}\sum_m \sum_n \alpha_2^{mn} \, log\left(\frac{P_t^m}{P_t^S s_{t\,t+1} - P_t^B \Omega^B - P_t^Q \Omega^Q}\right) log\left(\frac{P_t^n}{P_t^S s_{t\,t+1} - P_t^B \Omega^B - P_t^Q \Omega^Q}\right)$$

where $m,\ n\ \in \{B, Q\}$, α_2^{mn}=α_2^{nm}, and $s_t = \frac{S_{t,t+1}}{P_t}$. Using Roy's identity, the share of short-term government securities is $\gamma^B \equiv \frac{P^B B}{P^S S}$ and the share of long-term government securities is $\gamma^Q \equiv \frac{P^Q Q}{P^S S}$ = $1 - \gamma^B$.[21] These shares are given by

$$\gamma_t^m = \frac{P_t^m \Omega^m}{P_t^S s_t} + (1 - \frac{P_t^B \Omega^B + P_t^Q \Omega^Q}{P_t^S s_t}) \frac{\alpha_1^m \ + \ \sum_n \alpha_2^{mn} \, log\left(\frac{P_t^n}{P_t^S s_{t\,t+1} - P_t^B \Omega^B - P_t^Q \Omega^Q}\right)}{\sum_n \alpha_1^n \ + \ \sum_m \sum_n \alpha_2^{mn} \, log\left(\frac{P_t^n}{P_t^S s_{t\,t+1} - P_t^B \Omega^B - P_t^Q \Omega^Q}\right)} \tag{7.10}$$

Following Ellison and Tischbirek (2013), we assume that asset demands increase linearly with income. This implies $\alpha_1 \equiv \alpha_1^B$ and $\alpha_2 \equiv \alpha_2^{BB}$. The demands for short-term or long-term government securities are then

$$\frac{B_{t,t+1}}{P_t} = \Omega^B + \frac{P_t^S s_t - P_t^B \Omega^B - P_t^Q \Omega^Q}{P_t^B} [\alpha_1 + \alpha_2 log\ (\frac{P_t^B}{P_t^Q})] \tag{7.11}$$

$$\frac{Q_{t,t+\tau}}{P_t} = \Omega^Q + \frac{P_t^S s_t - P_t^B \Omega^B - P_t^Q \Omega^Q}{P_t^B} [1 - \alpha_1 - \alpha_2 log\ (\frac{P_t^B}{P_t^Q})] \tag{7.12}$$

[20] Pollak and Wales (1980)

[21] Barnett and Serletis (2008)

Assuming that cross-price effects are small, so α_2 is close to zero, the financial asset demand equation for long-term government security is approximated as

$$\frac{Q_{t,t+\tau}}{P_t} = \Omega^Q + \frac{1-\alpha_1}{\alpha_1}\frac{P_t^B}{P_t^Q}\left[\frac{B_{t,t+1}}{P_t} - \Omega^B\right] \tag{7.13}$$

To obtain the price of one-period securities, we note that nominal short-term interest rate paid on one-period security is

$$1 + i_t = \frac{1}{P_t^B} \tag{7.14}$$

Interest rate on long-term government securities is implicitly expressed as

$$P_t^Q = \frac{\frac{1}{\tau}}{1+i_t^Q} + \frac{\frac{1}{\tau}}{(1+i_t^Q)^2} + \quad \dots \quad + \frac{\frac{1}{\tau}}{(1+i_t^Q)^\tau} \tag{7.15}$$

$$= \frac{1}{\tau}\,\frac{1}{1+i_t^Q}\,\frac{1-\left(\frac{1}{1+i_t^Q}\right)^\tau}{1-\frac{1}{1+i_t^Q}}$$

where i_t^Q denotes per period interest rate corresponding to the price of long-term government security (P_t^Q).

7.1.4 Firms

There exist many intermediate goods producing firms operating under perfect competition. Intermediate goods producing firms produce output (Y_{mt}) using labor as the only input. In each period, a proportion $(1-\theta)$ of intermediate goods producing firms can adjust the price of their goods. Then, the production technology is assumed to be

$$Y_{mt} = A_t L_t^{\frac{1}{\psi}} \tag{7.16}$$

where A_t denotes total factor productivity and ψ_t is inverse of returns to scale in production.

All firms which alter their prices in period *t* select new price of their goods, $P_t(i)$. Hence, the optimization problem of such a firm is

$$\max_{P_t(i)} \; E_t \sum_{T=t}^{\infty} \theta^{T-t} \Lambda_{t,T} [P_t(i) Y_T(i) - W_T L_T(i)] \tag{7.17}$$

subject to

$$Y_T(i) = \left(\frac{P_t(i)}{P_T}\right)^{-\varepsilon_t} Y_t \tag{7.18}$$

where $P_t(i)$ represents the price of *i*-th good and stochastic discount factor is $\Lambda_{t,T} \equiv \beta^{T-t}\frac{\mu_T^C C_T^{-\delta} P_t}{\mu_t^C C_t^{-\delta} P_T}$.

Then, the firm's optimization problem is expressed as

$$max\ E_t \sum_{T=t}^{\infty} \theta^{T-t} \Lambda_{t,T} [\, P_t(i) \left(\frac{P_t(i)}{P_T}\right)^{-\varepsilon_t} Y_T - W_T \left(\frac{Y_t}{A_t}\right)^{\psi} \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon_t \psi - 1}] \tag{7.19}$$

The first order condition is

$$E_t \sum_{T=t}^{\infty} \theta^{T-t} \Lambda_{t,T} [\left(\frac{P_t^*(i)}{P_t}\right)^{-\varepsilon_t} Y_T - \left(\frac{P_t^*(i)}{P_t}\right)^{-\varepsilon_t} \varepsilon_t Y_T + \varepsilon_t \psi \frac{W_T}{P_T} \left(\frac{Y_t}{A_t}\right)^{\psi} \left(\frac{P_t^*(i)}{P_T}\right)^{-\varepsilon_t \psi - 1}] = 0 \tag{7.20}$$

Applying the real wage equation (7.5) and definition of stochastic discount factor, following equation can be obtained.

$$E_t \sum_{T=t}^{\infty} (\theta\beta)^{T-t} \mu_t^C C_T^{-\delta} Y_T \left(\frac{P_T}{P_t}\right)^{\varepsilon_t - 1}$$

$$= \left(\frac{P_t}{P_t^*(i)}\right)^{\varepsilon_t \psi + 1 - \varepsilon_t} E_t \sum_{T=t}^{\infty} (\theta\beta)^{T-t} \frac{\varepsilon_t \psi}{\varepsilon_t - 1} \mu_t^L L_t^{-\varphi} \left(\frac{Y_T}{A_t}\right)^{\psi} \left(\frac{P_T}{P_t}\right)^{\varepsilon_t \psi}] \tag{7.21}$$

Defining

$$F_{1t} = E_t \sum_{T=t}^{\infty} (\theta\beta)^{T-t} \mu_t^C C_T^{-\delta} Y_T \left(\frac{P_T}{P_t}\right)^{\varepsilon_t - 1}] \tag{7.22}$$

$$F_{2t} = E_t \sum_{T=t}^{\infty} (\theta\beta)^{T-t} \frac{\varepsilon_t \psi}{\varepsilon_t - 1} \mu_t^L L_t^{\varphi} \left(\frac{Y_T}{A_T}\right)^{\phi} \left(\frac{P_T}{P_t}\right)^{\varepsilon_t \varphi}] \tag{7.23}$$

Equation (7.21) can be rewritten as

$$\frac{P_t^*(i)}{P_t} = \left(\frac{F_{2t}}{F_{1t}}\right)^{\frac{1}{\varepsilon_t(\psi - 1) + 1}} \tag{7.24}$$

We also note that F_{1t} and F_{2t} can be expressed recursively as

$$F_{1t} = \mu_t^C C_t^{-\delta} Y_t + \theta\beta E_t \Pi_{t+1}^{\varepsilon_t - 1} F_{1t+1} \tag{7.25}$$

$$F_{2t} = \frac{\varepsilon_t \psi}{\varepsilon_t - 1} \mu_t^L L_t^{\varphi} \left(\frac{Y_t}{A_t}\right)^{\psi} + \theta\beta E_t \Pi_{t+1}^{\varepsilon_t \psi} F_{2t+1} \tag{7.26}$$

This price level is

$$P_t^{1-\varepsilon_t} = \theta (P_{t-1})^{1-\varepsilon_t} + (1-\theta)(P_t^*)^{\,1-\varepsilon_t} \tag{7.27}$$

By rearranging,

$$\frac{P_t^*(i)}{P_t} = \left(\frac{1 - \theta \Pi_t^{\varepsilon_t - 1}}{1 - \theta}\right)^{\frac{1}{1 - \varepsilon_t}} \tag{7.28}$$

Through combining equation (7.28) with equation (7.24), we obtain

$$\frac{1 - \theta \Pi_t^{\varepsilon_t - 1}}{1 - \theta} = \left(\frac{F_{1t}}{F_{2t}}\right)^{\frac{\varepsilon_t - 1}{\varepsilon_t(\psi - 1) + 1}} \tag{7.29}$$

7.1.5 Monetary and Fiscal Policy

It is postulated the policy rate is adjusted following a Taylor rule and asset purchase is conducted based on a Taylor-type asset purchase rule. The government issues short- and long-term government securities and collects lump-sum taxes for government spending.

(Monetary Policy)

Monetary policy objective is to stabilize inflation and output. The Central Bank alters the risk-free nominal rate (i_t) with a standard Taylor rule. Variables with no time identifier represent steady-state values.

$$\frac{1+i_t}{1+i} = (\frac{\Pi_t}{\Pi})^{\kappa_\pi}(\frac{Y_t}{Y})^{\kappa_y}u_t^i \tag{7.30}$$

where i_t is the risk-free nominal rate. κ_π denotes the policy reaction to inflation and κ_y denotes the policy reaction to output gap. u_t^i is an interest rate shock having an AR(1) process.

It is also postulated that the Central Bank conducts an asset purchase policy following the simple asset purchase rule.

$$\frac{Q - Q_{t,t+\tau}^{CB}}{Q} = (\frac{\Pi_t}{\Pi})^{\kappa_\pi^{AP}}(\frac{Y_t}{Y})^{\kappa_y^{AP}}u_t^{\xi} \tag{7.31}$$

where Q represents the long-term government securities and $Q_{t,t+\tau}^{CB}$ denotes the long-term government securities which the Central Bank purchases. κ_π^{AP} represents the policy reaction to inflation and κ_y^{AP} is the policy reaction to output gap. u_t^{ξ} is a large scale asset purchase shock, which follows an AR(1) process.

Equation (7.31) explains that $\Pi_t = \Pi$ and $Y_t = Y$ in steady-state. In this case, the right hand side is equivalent to 1, so the left hand side is also 1. This implies the Central Bank purchases no securities in steady state. Meanwhile, in a boom where $\Pi_t > \Pi$ and $Y_t > Y$, the right side equation is greater than 1. Thus, the left side equation is also larger than 1. This suggests that $Q_{t,t+\tau}^{CB} < 0$ and the Central Bank sells the securities. In contrast, in a slump where $\Pi_t < \Pi$ and $Y_t < Y$, the right side is smaller than 1. Therefore, the left side is also smaller than 1. This demonstrates that $Q_{t,t+\tau}^{CB} > 0$ and the Central Bank purchases securities.

With regard to issuance of government securities, it is assumed that the fiscal authority issues both of short- and long- term government securities. Such quantity of issued short-term government debt is determined to be consistent with the nominal policy rate. Meanwhile, for the long-term government security, the quantity of issued securities is set to follow the simple rule.

$$\frac{Q}{P_t} = gY \tag{7.32}$$

where $g > 0$ and Y denotes output in the steady state. The amount of the issued real long-term government securities in each period is set by government.

(Fiscal Policy)

Government finances its spending by collecting lump-sum taxes. Government spending evolves following AR(1) process.

$$ln\left(\frac{G_t}{G}\right) = \rho_G ln\left(\frac{G_{t-1}}{G}\right) + u_t^G \tag{7.33}$$

where *G* denotes the government spending value in the steady state ($T_t = P_t G_t$).

7.1.6 Resource Constraints

Economy wide resource constraint is

$$Y_t = C_t + G_t \tag{7.34}$$

Furthermore, aggregate supply of long-term government securities is same with the market demand for long-term government securities from banks and the Central bank.

$$Q = Q_{t,t+\tau} + Q_{t,t+\tau}^{CB} \tag{7.35}$$

7.2 Empirical Results

7.2.1 Calibration

With respect to setting up parameter values in this model, some parameters are calibrated referring to relevant literature. Average values of time-series statistics are used in calibrating some other parameters.

First, for the value of discount factor, the estimated value of Yie and Yoo (2011) is used. In addition, the horizon of long-term government security is set as 20 quarters reflecting that a 5-year government bond is generally considered as a typical long-term security in the financial market in Korea.

Next, asset values of short- and long-term government securities in steady-state are determined considering annualized interest rates of 3-month Monetary Stabilization Bonds and 10-year government bonds in Korea. For the asset demand equation, the parameters of α_1, α_2, Ω^B, and Ω^Q are decided following Chen et al. (2012) which argues that considerable literatures estimate a 3-15 bp decline in yields of the long-term government securities per the large scale asset purchase worth 100 billion.

For other parameters in the exogenous shocks, the values of Ellison and Tischbirek (2013) are extensively used. Furthermore, when it comes to the coefficients of simple standard Taylor rule, coefficients are optimally chosen to minimize the Central Bank loss function in terms of optimal simple rule.

Table 7.1: Calibrated Parameters

Parameters	Description	Value	Parameters	Description	Value
β	Discount factor	0.988	t_p	Share of firm profits from government	0.5
δ	Inverse elasticity of intertemporal substitution in consumption	2.0	g	Parameter in the long-term government security supply rule	0.66
φ	Inverse Frisch elasticity in labor supply	0.5	α_1	Parameter in asset demand equation	0.95
ε	Intra-temporal elasticity of substitution in the steady-state	6.0	α_2[22]	Parameter in asset demand equation	0
ψ	Inverse of returns to scale in production	1.1	Ω^B	Subsistence level of short-term government security in asset demand equation	10.21
θ	Probability of keeping prices fixed	0.85	Ω^Q	Subsistence level of long-term government security in asset demand equation	0.59
Π	Inflation in the steady-state	1.003	P^B	Price of short-term government security in the steady-state	0.9765
τ	Horizon of long-term government security	20	P^Q	Price of long-term government security in the steady-state	0.5636
G (=G/Y)	Government's expenditure/GDP ratio in the steady state	0.4			
< Parameters in exogenous shocks >					
Persistence			Standard Deviation		
ρ_ν	Interest rate shock	0.1	σ_ν	Interest rate shock	0.0025
ρ_ξ	Asset purchase shock	0.1	σ_ξ	Asset purchase shock	0.0025
ρ_C	Consumption preference shock	0.1	σ_C	Consumption preference shock	0.0025
ρ_L	Labor supply preference shock	0.7	σ_L	Labor supply preference shock	0.0025
ρ_G	Government spending shock	0.1	σ_G	Government spending shock	0.005
ρ_A	Technology shock	0.7	σ_A	Technology shock	0.01
ρ_ε	Substitution elasticity shock	0.95	σ_ε	Substitution elasticity shock	0.06

[22] Since the logarithmic part in the asset demand equation is not necessary if suggested model is solved by the first order approximation, value of α_2 which is the logarithmic part is set to zero in the model.

7.2.2 Experiment

The Central Bank loss function is postulated as

$$Loss = w_{\Pi}Var(\Pi_t - \Pi) + w_Y Var(Y_t - Y) + w_i Var(i_t - i) + w_Q Var\left(i_t^Q - i^Q\right) \qquad (7.36)$$

where w_{Π}, w_Y, w_i, and w_Q denote the relative weights for fluctuations of inflation, output, short- and long-term government security rate, respectively.

Monetary policy objective is to minimize the Central Bank loss in equation (7.36) which is equal to weighted sum of fluctuations of inflation, output, short-term rate, and long-term government security rate.

(Optimal Monetary Policy under No Interest Rate Stabilization)

In the first policy experiment, it is supposed the Central Bank is indifferent to stabilizing fluctuations of short- and long-term government security rate. Reflecting such assumption, the relative weights of short and long-term government bond interest rate (w_i, w_Q) are set to zero in the loss function.

Table (7.2) shows how the loss of Central Bank can be different depending on the coefficients in the policy rules of the Central Bank. In the first scenario, it is postulated the Central Bank utilizes only the short-term policy rate representing conventional monetary policy instrument but not unconventional monetary policy. The coefficients in the Taylor rule for short-term policy rate are chosen optimally to minimize given loss function. In the second scenario, it is postulated the Central Bank can use conventional and unconventional monetary policy instruments simultaneously. In this instance, coefficients in short-term policy rate rule are the same as the optimal coefficients in the first scenario. On the other hand, the coefficients in large scale asset purchase rule are selected optimally. Finally, in the third scenario, it is supposed the policy rate responds only to inflation fluctuations and large scale asset purchases respond only to output fluctuations. Hence, only the coefficient for inflation in policy rate rule and the coefficient for output in large scale asset purchase rule are chosen optimally. In other words, coefficient for output in policy rate rule and coefficient for inflation in asset purchase rule are fixed to zero for allocating conventional monetary policy to respond just to inflation and unconventional monetary policy to react just to output.

According to the results of these policy experiments, the optimal policy combination of short-term rate adjustment and large scale asset purchase seems to be that short-term policy rate is adjusted only responding to inflation fluctuation and large scale asset purchase is conducted only reacting to output fluctuations. Against this backdrop, it appears adjustment of short-term policy rate is more effective in stabilizing the volatility of inflation while large scale asset purchases are more successful in stabilizing output volatility. In this case, the loss is much lower.

However, it also proves that conducting conventional and unconventional monetary policy together is not an optimal policy mix when the Central Bank gives a huge weight to stabilizing volatility of inflation (w_{Π}=0.9). In other words, this can be interpreted that during some period such as a boom when the Central Bank more concentrates on inflation stabilization, conducting unconventional monetary policy such as asset purchase together with conventional policy may not be helpful in achieving the maximized social welfare.

This finding reflects individual impact of conventional or unconventional monetary policy on output and inflation can be different in that transmission channels of the two policies are different. Therefore, the influence of one conventional monetary policy like adjustment of short-term interest rate is not perfectly cancelled out by another unconventional monetary policy like large scale asset purchase.

From this perspective, in short, a conventional monetary policy instrument such as the short-term policy rate can be utilized harmoniously as a complement to unconventional monetary policy tool like an asset purchase even though the policy rate is above zero lower bound (ZLB).

Table 7.2: Optimal Monetary Policy under No Interest Rate Stabilization[23]

Relative Weights[24] in Loss Function (w_{Π}, w_Y, w_i, w_Q)	Scenario	Coefficients in Taylor Rule for Policy Rate (κ_{π}, κ_y)	Coefficients in Taylor Rule for Asset Purchase $(\kappa_{\pi}^{AP}, \kappa_y^{AP})$	$\mathrm{Var}(\Pi_t)$ $(\times 10^5)$	$\mathrm{Var}(Y_t)$ $(\times 10^5)$	Loss $(\times 10^5)$	Gain (%)	Corresponding Inflation Change (%p)
0.5, 0.5, 0, 0	1	1.85, 4.62	0.00, 0.00	1.744	0.885	1.315	-	-
	2	1.85(*f*), 4.62(*f*)	0.00, 0.00	1.746	0.884	1.315	-0.008	-
	3	2.22, 0.00	0.00, 19.8	1.871	0.525	1.198	8.856	0.613
0.7, 0.3, 0, 0	1	2.46, 4.10	0.00, 0.00	1.351	1.498	1.395	-	-
	2	2.46(*f*), 4.10(*f*)	0.09, -0.05	1.346	1.503	1.393	0.115	-
	3	1.99, 0.00	0.00, 15.2	1.507	0.975	1.347	3.424	0.332
0.9, 0.1, 0, 0	1	2.30, 3.54	0.00, 0.00	1.241	2.143	1.322	-	-
	2	2.30(*f*), 3.54(*f*)	0.00, 0.00	1.230	2.159	1.323	-0.092	-
	3	2.20, 0.00	0.00, 19.4	1.838	0.546	1.709	-29.305	-0.833

[23] Coefficients in Taylor rule for policy rate and coefficients in Taylor rule for large scale asset purchase are optimally chosen according to the optimal simple rule using *osr* command in *dynare*. On the other hand, coefficients (*f*) are artificially fixed regardless of optimal monetary policy.

[24] These represent relative weights for each fluctuation term such as inflation, output, short- and long-term interest rate of government security.

(Optimal Monetary Policy under Interest Rate Stabilization)

As a next policy experiment, it is supposed the Central Bank is also concerned with fluctuations of short- or long-term rate. According to the table (7.3), the Central Bank can be more effective in minimizing the loss when using large scale asset purchase together with adjustment of short term policy rate. It is shown the loss can be sharply reduced when large scale asset purchase is complementarily and harmoniously conducted with short term policy rate because large scale asset purchase is more effective in directly reducing volatility of long term interest rate in the bonds market including long term government securities than adjustment of short term policy rate. However, when all the four coefficients in the Taylor rules for policy rate and asset purchase are chosen optimally in scenario 4, the loss increases rather than in scenario 3 on the whole. From this aspect, it seems that concentration of each policy instrument on inflation or output is needed to minimize the Central Bank's loss if two monetary policy instruments should be used in combination.

Table 7.3: Optimal Monetary Policy under Interest Rate Stabilization

Relative Weights[25] in Loss Function (w_{Π}, w_Y, w_i, w_Q)	Sce-nario	Coefficients in Taylor Rule for Policy Rate (κ_{π}, κ_y)	Coefficients in Taylor Rule for Asset Purchase ($\kappa_{\pi}^{AP}, \kappa_y^{AP}$)	$\mathrm{Var}(\Pi_t)$ ($\times 10^5$)	$\mathrm{Var}(Y_t)$ ($\times 10^5$)	$\mathrm{Var}(i_t)$ ($\times 10^5$)	$\mathrm{Var}(i_t^Q)$ ($\times 10^5$)	Loss ($\times 10^5$)	Gain (%)	Corresponding Inflation Change (%p)
0.6, 0.4, 0.0, 0.0	1	2.15, 4.37	0.00, 0.00	1.54	1.14	9.97	540.00	1.379	-	-
	2	2.15(*f*), 4.37(*f*)	0.00, 0.00	1.54	1.14	9.97	540.00	1.379	-	-
	3	2.22, 0.00	0.00, 19.7	1.86	0.53	10.36	11.83	1.330	3.554	0.363
	4	-0.72, -2.84	5.68, 16.35	1.30	0.61	2.66	4.04	1.019	-	-
0.6, 0.3, 0.1, 0.0	1	1.84, 4.57	0.00, 0.00	1.73	0.90	9.22	400.00	2.231	-	-
	2	1.84(*f*), 4.57(*f*)	9.03, 13.9	1.99	0.84	4.68	130.00	1.909	14.421	-
	3	0.49, 0.00	0.00, 19.9	2.22	0.59	1.19	14.93	1.625	27.165	1.276
	4	2.53, 3.49	0.64, 19.8	2.23	0.74	7.66	19.83	2.324	-	-
0.6, 0.2, 0.1, 0.1	1	-1.17, 7.41	0.00, 0.00	6.58	1.04	10.07	77.34	12.894	-	-
	2	-1.17(*f*),7.41(*f*)	-2.46, 0.53	7.09	1.33	13.96	56.41	11.557	10.368	-
	3	1.10, 0.00	0.00, 19.9	2.05	0.56	3.10	10.47	2.711	78.978	5.232
	4	2.25, 4.42	-0.27, 20.0	2.75	0.51	7.84	21.14	4.647	-	-

[25] These represent relative weights for each fluctuation term such as inflation, output, short- and long-term interest rate of government security.

7.3 Conclusion

In this chapter, the relationship between conventional and unconventional monetary policy tool is analyzed through the approach of “preferred habitat model” of Ellison and Tischbirek (2013) incorporating the characteristics of New-Keynesian DSGE model.

First, it turns out that conventional monetary policy tool like adjustment of policy rate can be harmoniously utilized as a complement with unconventional monetary policy instrument like an asset purchase even though the policy rate above zero lower bound, except for some extreme cases. This implies that asset purchase policy can be routinely conducted in many emerging market economies together with adjustment of traditional short-term policy rate even when the policy rate in those emerging market economies does not approach the zero lower bound, differently from major advanced economies like the U.S. or the U.K. during the Great Recession.

Second, it also proves that conducting conventional and unconventional monetary policy together can be significantly contributed in minimizing the loss including the volatilities of short- or long-term rate. It is because large scale asset purchase can be more effective in reducing fluctuations of long term interest rate in the long term government security market than change of short term policy rate in light of direct intervention in the interest rate transmission channel.

Table 7.4: The Model Summary

Economic Agents	Equation
1. Households	
Euler equation	$\beta E_t[\frac{\mu_{t+1}^C}{\mu_t^C}(\frac{C_{t+1}}{C_t})^{-\delta}\frac{P_t}{P_{t+1}}]\frac{1}{P_t^S} = 1$
Labor supply	$\frac{W_t}{P_t} = \frac{\mu_t^L}{\mu_t^C} L_t^{\varphi} C_t^{\delta}$
2. Banks	
Demand of short-term government security	$\frac{B_{t,t+1}}{P_t} = \Omega^B + \frac{P_t^S s_t - P_t^B \Omega^B - P_t^Q \Omega^Q}{P_t^B}[\alpha_1 + \alpha_2 log\,(\frac{P_t^B}{P_t^Q})]$
Demand of long-term government security	$\frac{Q_{t,t+\tau}}{P_t} = \Omega^Q + \frac{P_t^S s_t - P_t^B \Omega^B - P_t^Q \Omega^Q}{P_t^B}[1 - \alpha_1 - \alpha_2 log\,(\frac{P_t^B}{P_t^Q})]$
Relationship between demands of short- and long-term government securities	$\frac{Q_{t,t+\tau}}{P_t} = \Omega^Q + \frac{1-\alpha_1}{\alpha_1}\frac{P_t^B}{P_t^Q}[\frac{B_{t,t+1}}{P_t} - \Omega^B]$
Short-term nominal rate	$1 + i_t = \frac{1}{P_t^B}$
Long-term nominal rate	$P_t^Q = \frac{1}{\tau}\frac{1}{1+i_t^Q}\frac{1-(\frac{1}{1+i_t^Q})^{\tau}}{1-\frac{1}{1+i_t^Q}}$
3. Firms	
Production function	$Y_{mt} = A_t L_t^{\frac{1}{\psi}}$
Final goods production	$Y_t = D_t Y_{mt}$
Auxiliary variable (F_{1t})	$F_{1t} = \mu_t^C C_t^{-\delta} Y_t + \theta\beta E_t \Pi_{t+1}^{\varepsilon_t - 1} F_{1t+1}$
Auxiliary variable (F_{2t})	$F_{2t} = \frac{\varepsilon_t \psi}{\varepsilon_t - 1}\mu_t^L L_t^{\varphi}\left(\frac{Y_t}{A_t}\right)^{\psi} + \theta\beta E_t \Pi_{t+1}^{\varepsilon_t \psi} F_{2t+1}$
Inflation dynamics	$\frac{1-\theta\Pi_t^{\varepsilon_t - 1}}{1-\theta} = \left(\frac{F_{1t}}{F_{2t}}\right)^{\frac{\varepsilon_t - 1}{\varepsilon_t(\psi-1)+1}}$
4. Monetary and Fiscal Policy	
Interest rate rule	$\frac{1+i_t}{1+i} = (\frac{\Pi_t}{\Pi})^{\kappa_\pi}(\frac{Y_t}{Y})^{\kappa_y} u_t^i$
Asset purchase rule	$\frac{Q - Q_{t,t+\tau}^{CB}}{Q} = (\frac{\Pi_t}{\Pi})^{\kappa_\pi^{AP}}(\frac{Y_t}{Y})^{\kappa_y^{AP}} u_t^{\xi}$
Quantity of issued long-term government security	$\frac{Q}{P_t} = gY$
5. Other Equations	
Economy resource constraint	$Y_t = C_t + G_t$
Aggregate supply and demand of long-term government security	$Q = Q_{t,t+\tau} + Q_{t,t+\tau}^{CB}$

Chapter 8. Conclusions

8.1 Main Findings

This thesis analyzes effectiveness of unconventional monetary policy mainly using the approach of New-Keynesian DSGE model which incorporates financial friction. Specifically, Dynamic Stochastic General Equilibrium model explicitly incorporating financial intermediaries like Gertler and Karadi (2011) and Gertler and Karadi (2013) are broadly utilized in the whole part of this thesis. Parameters are usually calibrated using Korean statistics and relevant literatures. Conceptually, in this thesis, enlarging monetary base through large scale asset purchase (LSAP) or foreign exchange intervention (FXI) is defined as typical monetary policy tool used in the implementation of unconventional monetary policy. Furthermore, the relationship between conventional and unconventional monetary policy is also examined in terms of the preferred habitat approach.

First, in chapter 3, applying Gertler and Karadi (2011) typed New-Keynesian DSGE model into Korean economy, the effectiveness of credit policy is analyzed for the two types of financial shocks. The two types of financial shock are negative capital quality and negative bank net worth shock. Both of shocks can arise under some financial distress such as Global Financial Crisis (GFC) in 2008.

According to simulation results, the credit policy intervention for the negative capital quality shock by the Central Bank makes the crisis less severe. Concretely, the credit intervention contributes to reduce the increasing of external finance premium (spread). Then, the Central Bank's credit policy intervention is also helpful in moderating fluctuation of output. On the other hand, the economic influence on inflation seems slight because inflation dynamics does not considerably change even after the intervention in the credit market. In addition, it proves that during the crisis, more aggressive credit policy intervention by the Central Bank can be more effective than a normal liquidity provision as a stabilization policy in terms of the intervention intensity.

Next, the credit policy intervention for negative bank net worth shock also makes the crisis less severe, similar to the case of negative capital quality shock. In a concrete way, the credit policy intervention also contributes to lower the increasing of external finance premium and is useful to moderate the fluctuation of output. The effect of the credit policy intervention on inflation is also trivial like the case of the intervention for the negative capital quality shock.

Putting together, the overall simulation results suggest that credit policy intervention contributes to moderate economic contraction, regardless of negative capital quality shock or bank net worth shock. However, because such policy experiment is conducted under the strong assumption of a closed economy, it is inevitable that the policy simulation result in the chapter 3 has some limitations in terms of policy implication, considering that Korea is a typical small open economy which can be significantly affected both in real and financial sector by exogenous global shocks.

Second, in chapter 4, it proves that for emerging market economies including features of a small open economy, effectiveness of unconventional monetary policy like the intervention in domestic credit or in foreign exchange market can be very different according to the source of shock during the crisis.

Regarding to negative global interest rate shock originated in external sector, it proves that the intervention in foreign exchange market can be more effective than the intervention in domestic credit market in moderating fluctuations of output and inflation. On the other hand, for negative capital quality or bank net worth shock originated in the domestic economy, it turns out that the intervention in domestic credit market is slightly better than the intervention in foreign exchange market in terms of policy effectiveness. It seems that such a difference mainly depends on whether the origin of the crisis is internal or external. Therefore, from a perspective of policy effectiveness, the Central Bank in an emerging market economy needs to conduct proper mixture of various unconventional monetary policy instruments considering different characteristics of shocks.

Third, in chapter 5, the effectiveness of two monetary policies such as traditional interest rate adjustment and the foreign exchange market intervention using foreign reserve are analyzed based on the model by Aoki, Benigno, and Kiyotaki (2016) which is the open economy version of Gertler and Karadi (2011).

The experiments for three kinds of shocks are conducted. Those three shocks are total factor productivity shock, capital quality shock, and global interest rate shock. For total factor productivity shock, it turns out that positive technological shock contributes to boost the whole economy into a boom. Next, for the negative capital quality shock, it reduces effective capital and then bank net worth also decreases. In addition, because of appreciated real exchange rate in the external sector, export decreases and import increases. Meanwhile, inflation rises rapidly at first and output drops by more than 1% at trough. Finally, for global interest rate shock, due to the increase in global interest rate, real exchange rate depreciates. Then, export increases and import drops. Against this backdrop, this channel can be helpful in boosting net output, consumption, and import limitedly. Meanwhile, as inflation increases and real exchange rate depreciates, bank net worth also decreases. This sort of mechanism can act as a catalyst for economic recession. Hence, when these two opposite effects are comprehensively considered in evaluating the influence of the rise in global interest rate, it synthetically proves that net output decreases by about 0.5% and consumption also drops by 0.5%.

Meanwhile, when it comes to policy simulation, according to the impulse response functions to foreign reserve policy when the Central Bank lowers its foreign reserve supply into foreign exchange market by 5%, it proves that the intervention using foreign reserve by the Central Bank can contribute to aggravate real activity through deteriorating financial intermediation to a certain degree. However, when these two opposite effects are considered synthetically, it seems that appropriate foreign exchange intervention using foreign reserve can be helpful in boosting inflation and output overall during the downturn. Simultaneously, it also proves that as the intensity of the intervention is stronger, as policy effectiveness is also bigger.

Fourth, in chapter 6, theoretical differences in policy effectiveness are analyzed in term of three perspectives applying Gertler and Karadi (2013) typed New-Keynesian DSGE model into Korean economy. Such three perspectives are related to the difference of policy which are between purchasing private securities and long-term government securities, between under zero lower bound and non-zero lower bound, and between household’s assets segmentation and non-assets segmentation.

Above all, according to policy simulations, it proves purchase of private securities can be more effective than purchase of long-term government securities when it comes to stabilizing financial market distress and boosting real activities such as investment and output. In other words, when it is postulated that intervention is conducted in the same degree, purchasing private securities including Mortgage-Backed Securities (MBS), corporate bonds, commercial papers, etc. can be more effective in boosting real activity and inflation than purchasing similar degree of long-term government securities during the crisis.

Next, it also turns out that the policy effectiveness for large scale asset purchase can be considerably different according to whether the economy is curbed by zero lower bound (ZLB) constraint or not. The result of policy experiment demonstrates that large scale asset purchase can be more effective when the zero lower bound constraint is maintained for some periods than when the nominal policy rate can be adjusted flexibly in reaction to a large scale asset purchase shock. Specifically, if the

Central Bank can adjust its policy rate flexibly and immediately, for instance following standard Taylor rule, with implementation of large scale asset purchase, the policy effectiveness of such asset purchase can be offset by flexible adjustment of policy rate.

Finally, the policy effectiveness of such large scale asset purchase can also become weaker when it is postulated that the household cannot directly hold any financial assets like long-term private securities and government securities. Namely, it proves that the increases in output and inflation through large scale asset purchase can be weakened when assuming there is no household’s assets segmentation in the securities market.

Fifth, in chapter 7, the relationship between conventional and unconventional monetary policy is examined through the approach of “preferred habitat model” of Ellison and Tischbirek (2013) which includes characteristics of canonical New-Keynesian DSGE model. However, financial friction is not incorporated in this model.

According to optimal monetary policy analysis, it proves that conventional monetary policy instrument like adjustment of short-term nominal policy rate can be harmoniously utilized as a complement with unconventional monetary policy like an asset purchase even though the policy rate is not restricted at zero lower bound, except for some extreme cases. This result argues that large scale asset purchase can be routinely conducted in many emerging market economies together with adjustment of short-term nominal policy rate even when the policy does not face zero lower bound, differently from major advanced economies like the U.S. or the U.K. during the Great Recession.

In addition, it also turns out that conducting conventional and unconventional monetary policy together can be considerably contributed to minimize the loss which is composed of the volatilities of short- or long-term government security interest rates. It is since large scale asset purchase can be more efficient in moderating the fluctuations of the interest rate in the long-term government security market than normal adjustment of policy rate because the Central Bank can directly intervene in the transmission channel of interest rate.

Therefore, in sum, considering all the comprehensive simulation results in chapter 3, 4, 5, 6, and 7, such a conclusion can be derived that if Bank of Korea conducts unconventional monetary policy utilizing some policy instruments such as large scale asset purchase or foreign exchange intervention, it would be able to considerably contribute to protect the collapse of abrupt financial intermediation in crisis and boost real activities such as investment and output in a deflationary environment. At the same time, it is also evident that according to the characteristic of each exogenous shock, proper unconventional monetary policy instrument under each specific economic situation can be largely different. Hence, in terms of this stance, Bank of Korea would have to be more careful in choosing the non-traditional monetary policy tool when they decide to conduct unconventional monetary policy actively in the future downturn. Furthermore, considering complementarity of conventional and unconventional monetary policy, it seems to be possible the Central Banks in emerging market economies are able to routinely use unconventional monetary policy instrument with traditional adjustment of short-term policy rate in normal time, not just in crisis, although policy rate is not restricted to zero lower bound.

8.2 Further Research

In this thesis, the policy effectiveness of alternative unconventional monetary policy instruments is reviewed theoretically in terms of DSGE framework. However, in this thesis, such an policy effectiveness analysis for enlarging monetary base or excess reserve of the Central bank have a tendency to mainly concentrate on large scale financial asset purchase program including long-term government bonds or private securities and foreign exchange intervention. This is because unconventional monetary policy has been conducted usually through large scale assets purchase in advanced economies (AE) such as US, EU, UK, and Japan and through the intervention in foreign exchange market in some small open economies such as Switzerland and Czech.

However, in Korea, it is evident that there are also other alternative unconventional monetary policy tools which Bank of Korea can use, instead of large scale asset purchase or foreign exchange intervention during economic downturn. First, because the financial structure of Korea is formed pivoting on banking sector rather than capital markets, expanding Central Bank money through increasing credit claims to banks may be more effective than direct asset purchase in boosting aggregate demand under some specific economic recession. For instance, Long-Term Refinancing Operation (LTRO) and Targeted Long-Term Refinancing Operation (TLTRO) by European Central Bank, Funding for Lending Scheme (FLS) and Term Funding Scheme (TFS) by Bank of England, or Loan Support Program (LSP) by Bank of Japan are typical representatives of Central Bank's lending policy for boosting real activity. In particular, if interest rate spread is not very huge, bank lending channel by expanding credit claims to banks can be operated more effectively than portfolio rebalancing channel by the Central Bank's direct large scale asset purchase.

Second, the Central Bank bill issued by Bank of Korea can be also widely utilized as an unconventional monetary policy instrument to boost real activity. Bank of Korea regularly issues the Central Bank bill which is called as Monetary Stabilization Bond (MSB) in order to manage superfluous liquidity for achieving inflation objective. In this regard, it can be regarded that Bank of Korea has an alternative option to increase monetary base by repurchasing Monetary Stabilization Bond issued without the need to newly purchase long-term government or private securities in a financial market directly. In light of this additional policy option of Bank of Korea, it seems that more research for analyzing the policy effectiveness of lending or Central Bank bill repurchase policy in Korea can be needed for future policy.

In addition, in this thesis, many parameters are usually calibrated using statistics, steady-state values, and parameter values in relevant literatures. Hence, it is inevitable that there are some limitations in reflecting the state of Korean economy exactly in this approach. From this perspective, if parameters are estimated applying Bayesian methodology in future research, the explanation of the model would be more reliable.

References

Adler, G., R. Lama and J. Medina (2016). "Foreign exchange intervention under policy uncertainty", *IMF working paper* No. 16/67.

Aghion, P., P. Bacchetta and A. Banerjee (2001). "Currency crises and monetary policy in an economy with credit constraints", *European Economic Review* 45: 1121-1150.

Agostini, G., J. P. Garcia, A. Gonzalez, J. Jia, L. Muller and A. Zaidi (2016). "Comparative study of central bank quantitative easing programs", *FRBNY.*

Angeloni, I., and E. Faia (2013). "Capital regulation and monetary policy with fragile banks", *Journal of Monetary Economics* 60(3): 311-324.

Aoki, K., G. Benigno and N. Kiyotaki (2016). "Monetary and financial policies in emerging markets", *Economic Growth and Policy Conference*.

Aslam, A., and E. Santoro (2008). "Bank lending, housing and spreads", *University Copenhagen Department of Economics Discussion Papers* No. 08-27.

Barnett, W. A., and A. Serletis (2008). "Measuring consumer preferences and estimating demand systems", *MPRA Paper University Library of Munich.*

Bauer, M. D., and G. D. Rudebusch (2014). "The signaling channel for Federal Reserve bond purchases", *International Journal of Central Banking.*

Bean, C., M. Paustian, A. Penalver and T. Taylor (2010). "Monetary policy after the fall", *Bank of England working paper.*

Beck, T., A. Colciago and D. Pfajfar (2014). "The role of financial intermediaries in monetary policy transmission", *De Nederlandsche Bank working paper* No. 420.

Bernanke, B., and M. Gertler (1989). "Agency costs, net worth and business fluctuations", *American Economic Review* 79(1): 14-31.

Bernanke, B., M. Gertler and S. Gilchrist (1999). "The financial accelerator in a quantitative business cycle model", *Handbook of Macroeconomics* 1: 1341-1393.

Borio, C. and P. Disyatat (2010). "Unconventional monetary policies: an appraisal", *The Manchster School* 78(1): 53-89.

Borio, C. and A. Zabai (2016). "Unconventional monetary policies: a re-appraisal", *Bank for International Settlements working paper* No. 570.

Breedon, F., J. S. Chadha and A. Waters (2012). "The financial market impact of UK quantitative easing", *Oxford Review of Economic Policy* 28(4): 702-728.

Carlos, G. (2013). "The small open economy model of unconventional monetary policies", *mimeo.*

Carlstrom, C. T. and T. S. Fuerst (1997). "Agency costs, net worth, and business fluctuations: A computable general equilibrium analysis", *American Economic Review* 87(5): 893-910.

Chen, H., V. Curdia and A. Ferrero (2012). "The macroeconomic effects of large-scale asset purchase programs", *The Economic Journal* 122(567): 289-315.

Christensen, I., and A. Dib (2008). "The financial accelerator in an estimated new Keynesian model", *Review of Economic Dynamics* 11(1): 155-178.

Christensen, Jens H. E. and G. D. Rudebusch (2012). "The response of interest rates to U.S. and U.K. quantitative easing", *The Economic Journal* 122(564): 385-414.

Christiano, L.J., M. Eichenbaum and C. Evans (2005). "Nominal rigidities and the dynamic effects of a shock to monetary policy", *Journal of Political Economy* 113(1): 1-45.

Christiano, L.J., M. Rostagno and R. Motto (2010). "Financial factors in economic fluctuations", *European Central Bank working paper* No. 1192.

Constancio, V. (2017). "The future of monetary policy frameworks", *mimeo.*

Cour-Thimann, P., and B. Winkler (2012). "The ECB's non-standard monetary measures: The role of institutional factors and financial structure", *Oxford Review of Economic Policy* 28(4): 765-803.

Curdia, V., and M. Woodford (2011). "The central bank balance sheet as an instrument of monetary policy", *Journal of Monetary Economics* 58(1): 54-79.

Darracq-Paries, M., Kok Sorensen, C., and Rodriquez Palenzuela, D. (2011). "Macroeconomic propagation under different regulatory regimes: Evidence from an estimated DSGE model for the Euro area", *International Journal of Central Banking* 7(4): 49-113.

De Graeve, F. (2008). "The external finance premium and the macroeconomy: US post WWⅡ evidence", *Journal of Economic Dynamics and Control* 32(11): 3415-3440.

Del Negro, M., G. Eggertsson, A. Ferrero and N. Kiyotaki (2011). "The great escape? A quantitative evaluation of the Fed's liquidity facilities", *Federal Reserve Bank of New York Staff Reports*.

Del Negro, M., M. P. Giannoni and F. Schorfheide (2013). "Inflation in the Great Recession and New Keynesian models", *Federal Reserve Bank of New York Staff Reports* No. 618.

Ellison, M., and A. Tischbirek (2014). "Unconventional government debt purchases as a supplement to conventional monetary policy", *Journal of Economic Dynamics and Control* 43: 199-217.

Fontaine, J., L. Suchanek and J. Yang (2017). "Unconventional monetary policy: the perspective of a small open economy", *Bank of Canada Review* Spring 2017: 19-30.

Gagnon, J., M. Raskin, J. Remache and B. Sack (2011). "The financial market effects of the Federal Reserve's large-scale asset purchases", *International Journal of Central Banking* 7(1): 3-43.

Gali, J. (2008). "Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework", *Princeton, New Jersey: Princeton University Press, 1 ed.*

Gambacorta, L., and B. Hofmann (2014). "The effectiveness of unconventional monetary policy at the zero lower bound: A cross-country analysis", *Journal of Money, Credit and Banking* 46(4): 615-642.

Gambacorta, L., and F. M. Signoretti (2014). "Should monetary policy lean against the wind?: An analysis based on a DSGE model with banking", *Journal of Economic Dynamics and Control* 43: 146-174.

Garcia-Cicco, J. (2011). "On the quantitative effects of unconventional monetary policies in small open economies", *International Journal of Central Banking* 7(1): 53-115.

Gerali, A., S. Neri, L. Sessa and F. M. Signoretti (2010). "Credit and banking in a DSGE model of the euro area", *Journal of Money, Credit and Banking* 42(1): 107-141.

Gertler, M., S. Gilchrist and F. Natalucci (2007). "External constraints on monetary policy and the financial accelerator", *Journal of Money, Credit and Banking* 39: 295-330.

Gertler, M., and P. Karadi (2011). "A model of unconventional monetary policy", *Journal of Monetary Economics* 58(1): 17-34.

Gertler, M., and P. Karadi (2013). "A framework for analyzing large-scale asset purchases as a monetary policy tool", *International Journal of Central Banking* 9(1): 5-53.

Gertler, M., and N. Kiyotaki (2010). "Financial intermediation and credit policy in business cycle analysis", *Handbook of Monetary Economics*, Vol. 3, North-Holland.

Gertler, M., N. Kiyotaki and A. Queralto (2011). "Financial crises, bank risk exposure and government financial policy", *mimeo*, New York University.

Goodfriend, M., and B. T. McCallum (2007). "Banking and interest rates in monetary policy analysis: A quantitative exploration", *Journal of Monetary Economics* 54(5): 1480-1507.

Guerrieri, L., and M. Iacoviello (2013). "Collateral constraints and macroeconomic asymmetries", *International Finance Discussion Papers* No. 1082, Board of Governors of the Federal Reserve System.

Haldane, A., M. Roberts-Sklar, T. Wieladek and C. Young (2016). "QE: the story so far", *Bank of England Staff Working Paper* No. 624.

Hamilton, J. M., and J. C. Wu (2012). "The effectiveness of alternative monetary policy tools in a zero lower bound environment", *Journal of Money, Credit and Banking* 44(1): 3-46.

Iacoviello, M. (2005). "House prices, borrowing constraints, and monetary policy in the business cycle", *American Economic Review* 95(3): 739-764.

Iacoviello, M. and S. Neri (2010). "Housing market spillovers: Evidence from an estimated DSGE model", *American Economic Journal: Macroeconomics* 2(2): 125-164.

Jensen, H. (2002). "Targeting nominal income growth or inflation?", *American Economic Review* Vol. 92(4): 928-956.

Jermann, U. and V. Quadrini (2012). "Macroeconomic effects of financial shocks", *American Economic Review* Vol. 102(1): 238-271.

Joyce, M., D. Miles, A. Scott and D. Vayanos (2012). "Quantitative easing and unconventional monetary policy – An introduction", *The Economic Journal* 122(564): 271-288.

Justiniano, A. and B. Preston (2010). "Monetary policy and uncertainty in an empirical small open-economy model", *Journal of Applied Econometrics* 25(1): 93-128.

Justiniano, A., G. Primiceri and A. Tambalotti (2010a). "Investment shocks and business cycles", *Journal of Monetary Economics* 57(2): 132-145.

Justiniano, A., G. Primiceri and A. Tambalotti (2011). "Investment shocks and the relative price of investment", *Review of Economic Dynamics* 14(1): 101-121.

Kabaca, S. (2016). "Quantitative easing in a SOE: An international portfolio balancing approach", *Bank of Canada Staff Working Paper* No. 2016-55.

Kang, H. D. (2007). "The change of real estate price and monetary policy response", *Quarterly Bulletin, in Korean.*

Kim, J., and B. H. Yoo (2008). "The role of money under an interest rate rule", *Journal of Money & Finance, in Korean*.

Kiyotaki, N., and J. Moore (1997). "Credit cycles", *Journal of Political Economy* 105(2): 211-248.

Kool, C. J. M., and D. L. Thornton (2012). "How effective is central bank forward guidance?", *Federal Reserve Bank of St. Louis Working Paper 2012-063A.*

Kotaro, I., M. Stone and E. Yehoue (2009). "Unconventional central bank measures for emerging economies", *IMF Working Paper* No. 09/226.

Krishnamurthy, A., and A. Vissing-Jorgensen (2011). "The effects of quantitative easing on interest rates: channels and implications for policy", *Brookings Papers on Economic Activity* 3-43.

Lam, W. R. (2011). "Bank of Japan's monetary easing measures: Are they powerful and comprehensive?", *IMF Working Paper* No. 11/264.

Lizal, L., and J. Schwarz (2013). "Foreign exchange interventions as an (un)conventional monetary policy tool", *BIS Papers* No. 73.

Martins, G. (2012). "Three essays on the credit dimension of monetary policy", *mimeo.*

Martins, G. and J. Salles (2010). "The credit dimension of monetary policy: lessons from developing economies under sudden stops", *mimeo.*

Meier, A. (2009). "Panacea, curse, or nonevent? Unconventional monetary policy in the United Kingdom", *IMF Working Paper* No. 09/163.

Modigliano, F. and R. Sutch (1966). "Innovations in interest rate policy", *American Economic Review* 56: 178-197.

Peersman, G. (2011). “Macroeconomic effects of unconventional monetary policy in the euro area”, *ECB working paper series* No. 1397.

Pollak, R. A. and T. J. Wales (1980). “Comparison of the quadratic expenditure system and translog demand systems with alternative specifications of demographic effects”, *Econometrica* 48(3): 595-612.

Smets, F., and R. Wouters (2003). “An estimated dynamic stochastic general equilibrium model of the euro area”, *Journal of the European Economic Association*, 1(5): 1123-1175.

Smets, F., and R. Wouters (2007). “Shocks and frictions in US business cycles: A Bayesian DSGE approach”, *American Economic Review* 97(3): 586-606.

Thornton, D. L. (2012). “Evidence on the portfolio balance channel of quantitative easing”, *Federal Reserve Bank of St. Louis Working Paper* 2012-015.

Thornton, D. L. (2013). “An evaluation of event-study evidence on the effectiveness of the FOMC’s LSAP program: Are the announcement effects identified?”, *Federal Reserve Bank of St. Louis Working Paper* 2013-033B.

Ueda, K. (2011). “The effectiveness of non-traditional monetary policy measures: The case of the Bank of Japan”, *The Japanese Economic Review* 63(1): 1-22.

Ugai, H. (2007). “Effects of the quantitative easing policy: A survey of empirical analyses”, *Bank of Japan Monetary and Economic Studies* No. 06-E-10.

Vayanos, D. and J. L. Vila (2009). “A preferred habitat model of the term structure of interest rates”, *CEPR Discussion papers.*

Villa, S. (2013). “Financial frictions in the euro area: A Bayesian assessment”, *ECB working paper series* No. 1521.

Yie, M. S., and B. H. Yoo (2011). “The role of foreign debt and financial frictions in a small open economy DSGE model”, *manuscript*.